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THE HEAT COAGULATION OF GLUTEN

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It has long been known that heating flour dry or in suspension in water to 60°-100°C. injures its gluten; and that in the baked loaf the nitrogenous substances have become for the greater part insoluble both in water and in aqueous alcohol. (Kalning, cited by Neumann, 1923, p. 384). This is attributed to coagulation of the gluten by heat. The temperature at which this occurs is given by Maurizio (1924) as 70° C., without information concerning how or by whom the observation was made. Neumann (1923, p. 203) is less definite, stating that by heating to 70°-100° C., temperatures that coagulate proteins, gluten is coagulated. Quite evidently this is merely inference not based on experimental evidence. The writers have been unable to find published experiments in which the temperature of coagulation of gluten has been determined. However, the behavior of one of the gluten proteins, gliadin, when heated, has been investigated. Heated with very weak alcohol, with water, or with strong alcohol it is gradually altered as indicated by Bogue (1924) and Dill and Alsberg (1925). In alcohol of 20 volume per cent it is gradually changed at low temperatures as shown by Gottenberg and Alsberg (1927). Concerning the temperature of coagulation of glutenin, there seems to be no record. We are therefore without adequate information concerning the coagulation temperature of gluten. The present investigation was designed to furnish information concerning the behavior of gluten when heated to different temperatures.

As glutenin is practically insoluble in water and gliadin is but slightly so, and as glutenin cannot be put into solution in any solvent without changing its colloidal state, the usual method of

determining the coagulation temperature of proteins, i.e., heating their aqueous solutions, could not be used. An indirect method had to be devised based on the assumption that coagulated gluten swells less readily in weak acid than undenatured gluten. This assumption proved to be justified. The technic employed was that of Upson and Calvin (1925).

Several different samples of family flour were used. The method was as follows:

Fifty grams of flour were doughed with 35 cc. of tap water and let stand under tap water for exactly one hour. The starch was then washed out under a gentle stream of tap water for exactly seven minutes. The gluten mass was then pressed between two wet glass plates with sufficient pressure on the top plate to flatten it out to about a quarter of an inch thickness. The same weight was used in most of the experiments. At the end of twenty-three minutes from the time it was pressed out, disks were cut from the gluten sheet by means of a cork borer. That is, one and one-half hours from the time of doughing twelve disks were cut and weighed from each gluten washing. In order to get as accurate weighings as possible of these little disks, they were rolled in the palm of the hand to remove as much adherent moisture as could be from the surface. They were weighed quickly to the third decimal place and put in a beaker containing water heated to the desired temperature. The beaker was then immersed in a water bath which was kept at the desired temperature to within one degree. After having been heated thirty minutes the disks were removed, cooled five minutes, and then put in weak acetic acid at room temperature. In different series of experiments the acid was of different strengths—N/50, N/200, N/400, and N/1000. After remaining in the acid two hours, the disks were removed and drained for fifteen minutes on a perforated glazed porcelain plate and then weighed quickly to the third decimal place. The relation of the final weight to the first weight, i.e., the increased weight due to imbibition of acid, was used as an index of the extent of denaturation of the gluten proteins. For the sake of convenience this weight relationship will be referred to herein as the *coefficient of imbibition*. It is calculated very simply by dividing the weight of the disk after swelling by its weight before it was heated.

The length of time necessary to heat the disks so as to raise the interior of the disks to the desired temperature was estimated by means of the mathematical theory of heat conduction under the assumption that the rate of heat diffusion is of the same order

of magnitude in gluten as in damp soil, damp soil being the substance most resembling gluten for which this rate is known. This calculation indicated that two minutes of heating should be sufficient.[1] The disks were actually heated for thirty minutes, thus allowing an ample factor of safety in case the assumption that damp soil and gluten have similar diffusivities is not fully justified. In these calculations as well as in the statistical analysis of the experimental data we enjoyed the cooperation of Dr. H. Hotelling, to whom we desire to express our appreciation.

Irregularities occurred in each series of experiments. No great regularity could be expected in any of the series because there are so many uncontrollable factors that determine the degree of swelling of gluten disks like those used in this investigation. The most important of these proved to be the ratio of the surface area to volume of the disks.

Unfortunately it was found quite impossible to prepare disks that were uniform in size, shape, and weight. These difficulties were met by experimenting upon large numbers of disks and subjecting the data obtained to statistical analysis. Nearly a thousand disks were used. The analysis of the data was comparatively simple. The irregularities largely disappeared if the observations were grouped by classes according to the weights of the disks before heating. The weight of a disk is apparently a good index of its surface–volume ratio. When the coefficients of imbibition of the same weight groups are compared, the results appear regular and consistent. It is perhaps worth while in this connection to point out that we have here an example of a procedure whereby an analytical method which is in itself subject to a wide margin of error may nevertheless be made to yield trustworthy conclusions. Such procedures might well be used more generally in biochemical work.

Table I gives the results of experiments with N/50 acetic acid, and Table II with N/400 acid.[2]

Table I is based on fewer data than Table II. Yet if the same weight classes be compared with one another it is obvious that the disks heated to 65° C. swelled less than those heated to 55° C., and that there is a tendency for the lighter disks to swell

1 For the details of the calculation see Appendix.

2 It will be noted that the writers got very much greater swelling in N/50 acetic acid than in N/400 acetic acid. This is not consistent with the statement of Upson and Calvin, (1925): "For hydrochloric acid the maximum absorption is obtained with a concentration of 0.005N, while the concentration for maximum absorption with lactic acid lies between 0.01N and 0.02N and for acetic acid is 0.04N."

more than the heavier ones. Study of the column giving the ratio of the 55° C. coefficients to the 65° C. coefficients shows that regardless of original size of disk, imbibition by those preheated to 65° C. is only about 87 per cent of the imbibition of those preheated to 55° C. Two of the classes (marked with an asterisk in the table) are exceptions, but these are also the classes with the smallest numbers of cases and therefore probably not significant. At any rate, disregarding these two small classes, in all other classes the relation of the swelling of gluten preheated at 55° C. to that of the gluten preheated at 65° C. is astonishingly similar, considering the numerous uncontrollable variables that enter into the experiments. The conclusion is warranted that heating gluten to 65° C. materially reduces its power to swell in acid as compared with heating it to only 55° C.

TABLE I

SWELLING IN N/50 ACETIC ACID OF DIFFERENT WEIGHT CLASSES OF GLUTEN DISKS HEATED TO 55°C AND 65°C.

Weight class	Imbibition coefficient 55°C.	No. of cases in class	Imbibition coefficient 65°C.	No. of cases in class	Imbibition coefficient 55°C. / Imbibition coefficient 65°C.
mg.					
<400	304	22	259	15	117
401-425	290	13	249	6	116
426-450	295	6	247	21	119
451-475	276	13	244	13	113
476-500	272	19	235	16	116
501-525	275	11	241	9	117
526-550	280	4	225	6	124*
551-575	265	5	227	6	117
576-600	237	1	226	1	105*
601-625					
626-650					
651-675			212	1	
676-700	207	1	212	1	
Average	270		234		115

*Exceptions as noted above.

In Table II the effect of heating over a wider range of temperature, 50° C. to 80° C., is recorded. Weaker acid, N/400, was used. The table summarizes the results obtained with over 600 disks. Two different samples of the same brand of flour were employed. As in Table I, data are grouped in classes according to the original weights of the disks. It is obvious that the capacity of each weight group to swell in acid becomes progressively less the higher the temperature to which the disks have been heated. There can be no doubt that some change occurs in gluten when heated to more than 50° C. that weakens its power to swell in acid.

TABLE II

SWELLING IN N/400 ACETIC ACID OF DIFFERENT WEIGHT CLASSES OF VARIOUSLY HEATED GLUTEN DISKS

Weight class	Average imbibition coefficients after various temperatures					Number of cases in class					Weighted average imbibition coefficient of all temperatures for each class
	50°C.	60°C.	65°C.	70°C.	80°C.	50°C.	60°C.	65°C.	70°C.	80°C.	
mg.											
<450	194	169	162	154	145	1	3	1	4	3	160
450-475	173	165	...	149	144	5	2	0	4	4	158
476-500	174	169	159	153	143	13	8	3	7	7	162
501-525	174	167	152	150	140	17	12	11	13	7	159
526-550	171	165	151	146	133	15	20	12	21	12	154
551-575	168	164	152	147	141	20	24	19	24	14	155
576-600	166	165	153	146	140	20	36	20	28	15	156
601-625	167	161	150	145	139	22	25	15	15	11	155
626-650	167	158	148	144	134	14	17	14	14	14	151
651-675	168	156	147	142	134	12	16	3	8	3	155
676-700	162	149	...	143	137	5	1	0	4	4	149
>700	162	...	136	142	...	8	0	1	1	0	157

Table II does not give a general survey of the data because it presents averages of different weight groups. To obtain a general survey of the data it is necessary in some manner to eliminate the grouping by weight. To do this, the weighted average imbibition coefficient in each weight class was first calculated. These averages form the last column of Table II. Then each of the coefficients was replaced by its deviation from the average for its weight class, thus forming Table III. Finally, each column of Table III was averaged, yielding for each temperature an effect upon imbibition coefficients which may be ascribed to preheating.

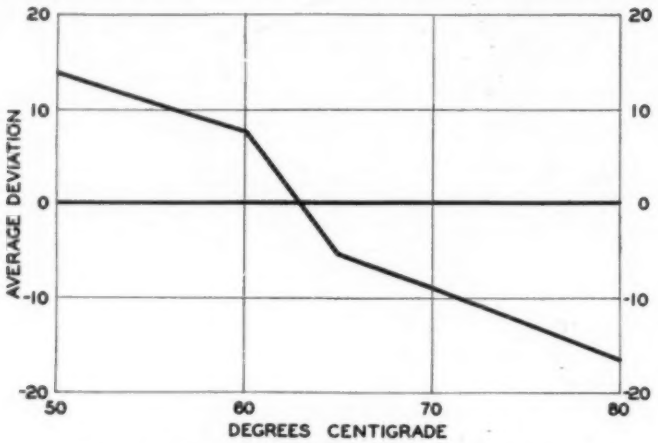
TABLE III

DEVIATION OF WEIGHTED AVERAGE IMBIBITION COEFFICIENT GIVEN IN TABLE II FOR EACH TEMPERATURE OF EACH WEIGHT CLASS FROM THE GENERAL AVERAGE OF ALL CLASSES AT ALL TEMPERATURES

Weight class	Temperature				
	50°C.	60°C.	65°C.	70°C.	80°C.
mg.					
<450	24	9	+2	−6	−15
450-475	15	7	..	−9	−14
476-500	12	5	−3	−9	−19
501-525	15	8	−7	−9	−19
526-550	17	11	−3	−8	−21
551-575	13	9	−3	−8	−14
576-600	10	9	−3	−10	−16
601-625	12	6	−5	−10	−16
626-650	16	7	−3	−7	−17
651-675	13	1	−8	−13	−21
676-700	13	0	..	−6	−12
>700	5	..	−21	−15	..
Average deviation for each temperature	+13.75	+7.2	−5.4	−9.1	−16.72

Table III gives all these figures. The figures themselves are abstract numbers. They do not represent weights or other measurements obtained by experiment though they are derived by simple calculation from such measurements. From Table III the conclusion must be drawn that gluten heated to 50° C. has an imbibition coefficient 13.75 units above that of the average of all the 600 disks; while gluten heated to 60° C. has an imbibition coefficient only 7.2 units above the general average. For gluten heated to 65° C., 70° C., and 80° C., respectively, the corresponding figures are negative, viz., —5.4, —9.1, and —16.72. Subjecting to the three higher temperatures, reduces imbibition appreciably below the general average.

The accompanying curve presents these figures graphically. It will be seen that the rate of fall of the imbibition ratio is rather steady except between 60° C. and 65° C., where the drop is more



Average Deviation for Each Temperature from the Group Weight Average for all Temperatures

abrupt. The conclusion seems therefore warranted that the alteration of gluten by heat is a continuous process in the range between 50° C. and 80° C. and takes place more rapidly between 60° C. and 65° C. than at other intervals over this range. Certainly there is no indication of a coagulation temperature for gluten at 70° C. as given by Maurizio (1924).

An attempt was made to study the swelling of gluten that had been heated to 100° C. This failed because at this temperature the disks puffed up, owing to the formation of steam pockets. Subsequently some of them collapsed more or less. In consequence, they presented greatly varying surfaces to the acid and also retained greatly varying quantities of liquid in their inter-

stices, like a sponge. To the eye there seemed to be very little swelling as compared with gluten disks that had been heated to lower temperatures; yet weighings showed a greater imbibition coefficient, which is to be attributed presumably to spongy texture.

When the experiments described were planned it was thought improbable that a temperature as low as 50° C. would alter gluten. The results obtained, however, brought this well within the range of possibilities; therefore supplemental experiments were undertaken at lower temperatures. Three sets of disks were allowed to swell in N/400 acid: one without any preheating, another preheated to 40° C.; and the third preheated to 50° C. The disks that were not heated were placed in the acid at once. The two other sets of disks were first heated. It was found that subjecting gluten to the higher temperature increased its coefficient of imbibition, in other words, its capacity to swell became greater. For the unheated disks, the coefficient of imbibition was 158; for the disks preheated to 40° C., it was 179; for those preheated to 50° C., it was 183.

As a check, another series of experiments was made using still weaker acid, N/1000. In this series one set of disks was preheated at 30° C., one at 40° C., and one at 50° C. For the disks that had been held at 30° C., the coefficient of imbibition was 134; for those held at 40° C., it was 133; and for those held at 50° C., it was 139. In acid of this strength, therefore, no marked differences were observed.

The results in N/400 acid were so consistent that they must be significant. In explaining them, two factors, aside from alteration of the gluten proteins themselves, require consideration. One is that warming in water causes gluten to absorb water. The other is swelling of starch.

That warming in water causes gluten to absorb water has been shown definitely by Upson and Calvin (1915). Moreover, it has long been known that as the temperature of the wash water increases, yields of wet gluten increase. See Dill and Alsberg (1924). It is probable that the prewarming which the gluten disks received caused them to swell somewhat before they were placed in acid. Such preswelling, as may be deduced from the data of Upson and Calvin, is too slight to account for more than a portion of the total swelling as measured after the sojourn in acid. It is easily possible, however, that preswelling, while in itself not great, facilitates subsequent swelling in acid.

Relatively low temperatures cause starch to absorb moisture and swell. Neumann (1923) recognized that this may begin at as low a temperature as about 50° C. La Wall and Graves as well as the writers[3] have found that it begins to some extent at even lower temperatures. If it occurs to an appreciable degree at a temperature as low as 40° C. then the increases in weight of the disks above recorded as "imbibition coefficients" might be due in part to the beginning of the swelling of starch. Starch swelling cannot, however, be responsible for the greater part of the swelling of gluten preheated to 50° C. as compared with unheated gluten, for in that event the imbibition coefficients should be about the same in strong and in weak acid, acid not having much effect on starch. Actually they are not.

What rôle starch actually plays could be determined most easily by experimentation with gluten free from starch. Unfortunately, its preparation is as yet impossible (Dill, 1925). However, it is feasible to obtain gluten with relatively low starch content if the flour is first ground for a long time in a pebble mill in order to break up the clumps of gluten, thus liberating the starch grains; at the same time many of the grains are cracked, thereby rendering much of the starch substance soluble in cold water (Alsberg and Griffing, 1925). The gluten prepared from such overground flours may contain only two-thirds as much non-protein material as gluten prepared from the same flour not subjected to overgrinding, as the writers have determined by actual analysis.

Two glutens, samples A and B, were washed from the flour overground for 16 hours that had been used in the experiments of Table V of the writers' earlier paper on overgrinding flour (Alsberg and Griffing, 1925). This flour was, of course, not merely overground, but also overaged, having been stored in a closed vessel in the laboratory for more than 18 months after it was ground. The imbibition coefficients obtained with it, after heating to 30° C., 40° C., and 50° C., are recorded in Table IV. Imbibition is much less than it was when the experiments reported in the earlier paper on overgrinding flour were carried out, owing, no doubt, to overaging. In the earlier experiments the swelling was, in round numbers, about seventy per cent as great as that of the disks made from the same flour in the normal state. If the data of Table IV be adjusted to that basis, then the imbibition coefficients are of the same magnitude as those obtained in the other experiments reported

[3] Unpublished observations.

above, in which the disks were heated to 30° C., 40° C., and 50° C. There is, then, no evidence that in gluten subjected to temperatures below 50° C. gelatinization of starch plays a major rôle in increasing the swelling power of gluten. Probably preswelling of gluten, due to the preheating, and swelling of starch together contribute only in a minor way to the final effect of acids.

TABLE IV

SWELLING IN N/400 ACID OF VARIOUSLY HEATED GLUTEN DISKS FROM OVERGROUND FLOUR

Heat treatment of disks	Gluten A imbibition coefficient	Gluten B imbibition coefficient
°C.		
30	125	122
	127	122
	120	122
	129	132
40	128	139
	128	132
	128	141
	133	142
50	138	144
	137	136
	135	135
	137	133

While, then, it is unlikely that swelling of starch plays a pronounced rôle in determining the imbibition coefficient when the gluten is heated to 50° C. or less, it is quite likely that it does play a rôle when the heating is higher. Above 50° C. the swelling of wheat starch becomes progressively greater. No doubt gelatinization of starch at these temperatures tends to cause imbibition of water by the gluten as it is heated and thus to mask, more or less, the tendency of the higher temperatures to lessen the capacity of the gluten to swell. In all probability, the effects of heating gluten would have appeared more pronounced than they did in our experiments had it been possible to work with starchless material.

The next question that arises is whether the changes in gluten above recorded are due to alteration of the glutenin or of the gliadin. No way of determining alteration of glutenin by itself has occurred to the writers. It seemed, however, probable that any change in the gliadin might manifest itself in a lessening of the amount of nitrogenous material that could be extracted from the heated gluten with 65% alcohol.

Accordingly, gluten disks were heated for thirty minutes to 50° C., 60° C., and 70° C. Samples weighing approximately 1.5 gm. were transferred to Erlenmeyer flasks and extracted on a water bath for

more than a week with 65% alcohol. The alcohol was renewed at frequent intervals. At each change of alcohol, the extract in the flasks was filtered through quantitative filter paper into a Kjeldahl flask, care being taken to hold back all the solid material in the extraction flask. Finally, after the week extraction, the residues were transferred to the filter papers and allowed to drain completely. The filter papers and contents were then transferred to other Kjeldahl flasks and nitrogen was determined separately in the alcoholic extracts and in the residues. Table V gives the nitrogen content in milligrams of the alcohol-soluble portions, and of the alcohol-insoluble portions, respectively. The last column on the right represents the ratio of alcohol-soluble to alcohol-insoluble proteins, or the gliadin-glutenin ratio.

TABLE V
GLIADIN-GLUTEN RATIOS OF GLUTEN HEATED TO VARYING TEMPERATURES

Temperature	Alcohol-soluble nitrogen		Alcohol-insoluble nitrogen		Gliadin-glutenin ratio	
	Gluten A	Gluten B	Gluten A	Gluten B	Gluten A	Gluten B
°C.	mg.		mg.			
50	59.8	47.5	33.1	28.3	1.81	1.68
60	49.4	49.2	31.2	30.6	1.58	1.61
70	47.8	47.6	35.0	34.1	1.36	1.40

The table shows that the gliadin becomes progressively less soluble as the temperature to which the gluten was heated before extraction increases. This result is consistent with the observations upon the effect of heat on the coefficient of imbibition of gluten. Whether the gliadin actually suffers a change in solubility or whether it merely becomes more difficult to extract, it is difficult to say. It is quite possible that the glutenin becomes coagulated, thereby mechanically shutting off the solvent from the gliadin so that it is less easily extracted. That the gliadin remains unaltered is, however, improbable in view of the findings of Gottenberg and Alsberg (1927). Possibly both phenomena are factors entering into the results of the experiments.

Discussion

The observations recorded in this paper may have practical significance. If it is true that the swelling power of gluten is enhanced at relatively low temperatures, then it is quite conceivable that the effects of carrying on dough fermentations at relatively high temperatures as is recommended in the "no dough-time" process, are not solely the results of more rapid growth of yeast, but also of change in the colloidal properties of the gluten. To be sure, even the highest temperatures used for fermentation in the bakeshop are lower than those used in present investigation. Nevertheless, at lower temperatures similar effects merely less in degree are conceivable. What is needed is a study

of the imbibing power of gluten within the range of the fermentation temperatures in the bakeshop. Such an investigation will be undertaken by the writers. That changes may be found seems not at all unlikely. It is even possible that alteration of the gluten proteins through contact with water may be a factor in the "development" of gluten in doughing flour and also in the "maturation" of gluten during fermentation. These are problems for future study.

The observations recorded in this paper also indicate that changes in the gluten begin to occur in dough placed in the oven at lower temperatures than has commonly been supposed. This may be significant in explaining the different effects obtained in baking pieces of dough of different sizes at the same temperature or pieces of dough of the same size at different temperatures. The fact that the coagulation of gluten does not take place all at once at a given temperature but progressively as the temperature rises, is also significant. It is notable, too, that even after exposure to a moist heat of 80° C. for 30 minutes gluten still retains a very appreciable power to swell in weak acid. It is probable, therefore, that in bread it has not lost all its colloidal properties as completely as some have assumed. It may play an important rôle in the growing stale of bread.

Summary

Heating gluten alters its power to swell in acid. The swelling power becomes less, as the temperature increases from 50° to 80° C. If the swelling power of gluten heated to different temperatures from 50° to 80° C. be plotted against temperature, a graph is obtained that is a straight line except at 60° to 65° C., where its downward slope is steeper than over other portions of the chart. Except at this temperature, there is no indication of any definite coagulation temperature. Denaturation seems to take place over the whole range from 50° to 80° C. At temperatures from 30° to 50° C. there is no impairment of swelling power; on the contrary, evidence was obtained indicating that swelling power is somewhat increased.

Appendix

The time required to raise the disk practically to the desired temperature may be estimated by means of the mathematical theory of heat conduction. If the surfaces of a slab of thickness, l, which was initially at uniform temperature v_0, be maintained at temperature v_1, the tem-

perature at a distance x from one face will at time t be

$v = v_1 + (v_0 - v_1)\ \frac{4}{\pi}(y \sin \frac{\pi x}{l} + \frac{y^3}{3} \sin \frac{3\pi x}{l} + \frac{y^{25}}{5} \sin \frac{5\pi x}{l} + \ldots)$,

where $y = e^{-h^2 \pi^2 t / l^2}$, h^2 being the "diffusivity" of the substance. This equation takes no account of heat flowing in from the edges. At the center $x = l/2$ and

$v = v_1 + (v_0 - v_1)\frac{4}{\pi}(y - \frac{y^3}{3} + \frac{y^{25}}{5} - \ldots)$

The maximum value of $v_1 - v_0$ is about 70° C., while the temperature of the bath was maintained with an accuracy of about half a degree. Let us consider the time necessary to raise the center of the mass to a temperature so close to that of the surface that the quantity $\frac{v_1 - v}{v_1 - v_0}$ shall be less than 1/145. We shall then have

$y - \frac{y^3}{3} + \frac{y^{25}}{5} - \ldots = \frac{\pi}{4}\ \frac{v_1 - v}{v_1 - v_0} < .0054$

Obviously this is satisfied if $y < .0054$; that is, if

$$t > .53 \frac{l^2}{h^2}$$

Of the substances for which diffusivities have been compiled by Ingersoll and Zobel (1913), that which seems most to resemble dough is slightly damp soil, with a diffusivity in the neighborhood of $h^2 = .005$. For unit thickness this would indicate a required time of 106 seconds or less than two minutes. Since none of the disks used were as much as a centimeter thick, and since the assigned temperature must reach most of the mass long before penetrating to the center, the thirty-minute period used seems ample in spite of the possibility that heat may advance somewhat less rapidly than in damp soil.

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VALUE OF HYDROGEN-ION CONCENTRATION AND BUFFER VALUE DETERMINATION IN TESTING AND USE OF FLOURS

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This subject is very comprehensive in its scope and one upon which some confusion has resulted. In presenting it I shall analyze closely some of the contributing factors that lend to development of dough which will result in bread that to the skilled baker is the finished record from which he can estimate the manner in which these factors of bread development have been brought into play. Let us trace some of the forms of bread development that present themselves for our control and see in what degree each contributes to the development of the finished bread. As we trace each of these we shall see whether these factors bear any relation to the hydrogen-ion concentration or buffer value of the flour, dough, or bread.

First, mechanical development. Swanson and Working have greatly extended our knowledge along these lines. Apart from any other factors, flours differ greatly as to the mechanical mixing or treatment they must undergo to produce good bread. In Table I are set forth the results of two extreme types of mechanical mixing on the same flour. Loaves 1 and 2 were made by the Werner method, which is essentially a hand-mixing method and probably represents a minimum of mechanical development.[1] In loaves 3 and 4, the same formula was employed but with proportions large

[1] On Tables I, II, III, VII and VIII, the time to the first punch was 2 hours; to the second, 1 hour; and a resting period of ½ hour was given before panning. The scaling weights of dough in all these tables were the same.

enough to mix on a laboratory Fleischmann or Bachman mixer. This mixer was run at 100 r.p.m.[2] Table I sets forth the conditions and gives a comparison of the resulting bread. The temperature of all doughs referred to in this paper was 79° F. Fermentation took place at 79° to 80° F.; proof box temperature was 95° F.

TABLE I
MECHANICAL DEVELOPMENT

Loaf No.	Mixed by	Time of mixing	Proof period	Volume	Increase in volume	Score of bread and comments
		min.	min.	cu. in.	%	
1	Hand	4	55	28.5	..	Very poor texture, open grain, honeycomb structure
2	"	4	55	28.4	..	Very poor texture, open grain, honeycomb structure
3	Machine	15	55	31.9	12.2	Very good loaf of bread, good texture, close grain
4	"	15	55	31.3	10.0	Very good loaf, well developed

Loaves 3 and 4, which are checks, have an average increase in volume of 11.1% over loaves 1 and 2, the hand-mixed loaves. Attention is called to the fact that all the loaves have the same H-ion concentration, namely pH=5.68. This would be the logical expectation, as all were given the same fermentation period. It is interesting to note how two different conclusions could be reached in regard to the same flour with all other conditions the same except the mixing. This emphasizes the need of a standard baking test.

The second form of development to which we shall turn our attention is that caused by the addition of chemicals, either to the flour direct or as an ingredient of the dough batch. In this second type, attention is called to the action of acids, employing the same flour but using only hand mixing. Results are shown in Table II.

TABLE II
DEVELOPMENT BY ACIDS

Loaf No.	Mixed by	Time of mixing	Ingredient added	Volume	Increase in volume	Score of bread and comments
		min.		cu. in.	%	
1	Hand	4	0.1 gm. tartaric acid	30.7	4.7	All good
2	"	4	0.1 " " "	30.7	4.7	" "
3	"	4	Control	29.5	..	Very poor
4	"	4	"	29.0	..	" "

The H-ion concentration of the bread from loaves 1 and 2 was pH=5.25, and in the controls, it was pH=5.65. In loaves

[2] Before baking, the doughs in 3 and 4 were scaled to the same weight as 1 and 2.

1 and 2, there is an increase in volume of 4.7% with a very remarkable improvement in color and general development. This improvement has been pointed out by many investigators. Attention is called to the fact that this development by acid took place when the mechanical development was at a minimum.

As another example of the second form of development, mention should be made of the effects produced by oxidizing agents.

In Table III this unbleached flour was treated with one milligram of potassium bromate to 100 grams of flour. Thus by the addition of potassium bromate we have increased the volume approximately 15%, while a similar increase has occurred in exactly the same flour bleached at the mill. The pH of this finished bread was approximately the same. It is thus possible to produce development by certain oxidizing agents and yet have a constant H-ion concentration.

TABLE III
DEVELOPMENT BY OXIDIZING AGENTS

Loaf No.	Mixed by	Time of mixing	Ingredient added	Volume	Increase in volume	pH of bread	Score of bread and comments
1		min.		cu. in.	%		
	Hand	4	Control	29.5	..	5.4	Very poor, undeveloped
2	"	4	"	29.3	..	5.4	No development, honeycomb appearance
3	"	4	1 mg. $KBrO_3$	34.0	15.7	5.35	Well developed
4	"	4	1 mg. $KBrO_3$	33.9	15.3	5.33	Same as No. 3, with much whiter crumb color, and superior texture and grain
5	"	4	Bleached at mill	33.5	14.0	5.32	Very well developed
6	"	4	Bleached at mill	34.3	16.7	5.35	Well developed

The action of many other chemicals could be considered. However, we shall touch on only one—sodium chloride. In Table IV are given the results obtained by an increase in the percentage of salt.

TABLE IV
THE ACTION OF SALT

Loaf No.	Salt	Volume	H-ion concentration of bread	Reading of gravimetric penetrometer	Score of bread
	%	cu. in.	pH	cm.	
1	0	171	5.20	16.3	Dull, very open
2	1	180	5.20	15.5	Fair +
3	2	196	5.17	15.0	Good
4	3	200	5.15	14.5	Good +
5	4	204	5.10	14.2	Good, but slightly salty

These were obtained on a 5-hour sponge with 10 minutes dough time. The very small decrease in the pH of the bread was caused by the proof time of the doughs, those with the higher percentage of salt were somewhat longer. It is possible with some flours to produce a great variation in breads with practically the same H-ion concentration. As the percentage of salt increases, the doughs become much tougher and stiffer, as shown by the readings in column 5.[3] The difference between the extremes is equivalent to about 2.8% in absorption. It is possible that the salt increased the strength of the dough mass, which allowed a better retention of the gas and resulted in an improvement in the bread.

A third form of development will be considered—that of enzymatic activity.

It has been shown by Rumsay (1922) that diastase possesses its maximum activity in a medium, the H-ion concentration of which is equivalent to pH 4.7 to pH 5.0. Grewe and Bailey (1927) state that:

"Rate of change in diastatic activity with increasing hydrogen-ion concentration was not uniform in all flours. Flours with a high initial diastatic activity exhibit greatest rate of increase in that property when acids are added. Diastatic activity in a dough is inhibited by the addition of alkali and it becomes necessary to compensate for the reduced diastatic activity in dough by the addition of material containing active diastase when baking properties of an alkaline dough are determined. Alkaline dough containing added diastase was converted into bread that was superior to that produced from control doughs to which no alkali had been added."

Grewe and Bailey have concluded from their work that the addition of acids or the increase in hydrogen-ion concentration of a dough does not result in an improvement of the physical properties but rather impairs such properties.

Maltase, which converts maltose into glucose, has an optimum H-ion concentration in the range between pH=4.5 to pH=5.0. Invertase, which is secreted by the yeast cell, has been shown by Sorensen to have an optimum zone between pH=4.5 and pH=5.0.

[3] For some time I have felt the need of a means of recording the stiffness or toughness of a dough. After trying many different kinds, a gravimetric plunger was found to be very satisfactory. Gravity, which can be corrected for so that the same momentum can be obtained at various places, has been employed. Another good feature is that friction enters to a very small extent. I have made use of this apparatus for over a year and have found it to give very valuable information. With it, several determinations can be made on a dough in about a minute. This is of great advantage. While claiming no great degree of accuracy for this apparatus, I have used it to report the data obtained in these experiments. It is far better than descriptive words. The weight of this plunger is 1070 grams. It is 310.5 mm. long and 21.14 mm. in diameter and the distance from the bottom of the plunger to the surface of the dough is 2.796 meters. The dough container was 4 inches in diameter and 12 inches in height.

He has further shown that by an increase in pH value, a great decrease in the activity of the enzyme is brought about.

Yeast itself is somewhat favored by increased hydrogen-ion concentration and it is very probable that the fermentation is somewhat increased by an increase of the hydrogen-ion concentration of doughs as they come from the mixer.

The proteolytic enzymes are no doubt of importance. On an average, their optimum H-ion concentration will probably be in the range between pH=4.4 and pH=5.0. Adler has shown that the protease of malt reaches its optimum activity at pH=5.0. Considering the actions of these proteolytic enzymes in the dough batch, it is important that they should proceed only to a small extent, but if carefully controlled, proteases may be used to condition gluten for good bread production, as shown by Weaver and Goldtap. If they are allowed to react to any great extent, the gluten or proteins of the flour will be broken down to a considerable extent. It is true that the yeast cell assimilates some of the products of hydrolysis of the proteins, which may result in an increased activity of the yeast. However, it is believed that this takes place to a very small extent.

High diastatic malts are, as a rule, accompanied by high proteolytic activity. It is probably for this reason that some bakers have hesitated to increase the diastatic activity of their flours by the addition of diastatic malts. In Table V are given some very interesting data showing how the addition of malt causes the dough to slack during its process of fermentation.

TABLE V

SLACKING OF DOUGHS BY ENZYMES PRESENT IN MALT

Dough No.	Mixed by	Time of mixing	Fermentation period of sponge	Malt or cane sugar	Distance penetrated by gravimetric penetrometer	Remarks on dough
		min.	hr.	%	cm.	
1	Machine	10	5	0.0	15.6	Very good
2	"	10	5	2.0 Malt	18.0	Sticky
3	"	10	5	4.0 "	20.0	Very sticky, could not get through machines
4	"	10	5	6.0 "	22.0	Stickier than No. 3
5	"	10	5	8.0 "	24.25	Too sticky to handle
6	"	10	5	0.0	15.5	Good
7	"	10	5	2.0 Cane sugar	15.7	"
8	"	10	5	4.0 " "	15.9	"
9	"	10	5	6.0 " "	16.4	"
10	"	10	5	8.0 " "	16.8	"

The malt had a diastatic value of 35 degrees Lintner, which was accompanied by a high proteolytic activity. The readings of the gravimetric penetrometer were taken immediately after the doughs came out of the machine, preparatory to their 10-minute resting or fermentation period in the dough stage. At this stage practically all of the gas has been expelled by mixing, and readings with the penetrometer can be very easily recorded. The maximum difference between the control dough with no malt, and the dough with 8% malt, is 8.65 cm. which is 11.5% decrease in water absorption or 1.44% decrease for every percentage of malt added. The per cent absorption reported was so corrected that the doughs carrying malt and those with cane sugar had a quantity of water added equivalent to 60%. In the doughs that contained cane sugar, a difference of 1.1 cm. occurred, which is equivalent to about 1.6% in absorption or about 0.18% for every percentage of cane sugar.

Table VI gives the data obtained when the percentage of malt referred to in Table V was kept constant and the pH of the doughs coming from the mixer varied as shown in the table.

TABLE VI

STIMULATION OF ENZYMATIC ACTIVITY BY ACIDS

Dough No.	Mixed by	Time of mixing	Fermentation period		Absorption	Malt added	Distance penetrated by gravimetric penetrometer	H-ion concentration of sponge when discharged from mixer
			sponge	dough				
		min.	hr.	min.	%	%	cm.	pH
1	Machine	10	5	10	60	0.0	15.9	6.25
2	"	10	5	10	60	2.0	16.5	5.60
3	"	10	5	10	60	2.0	17.6	5.40
4	"	10	5	10	60	2.0	17.9	5.20

Thus, by increasing the initial H-ion concentration of the sponge and fermenting 5 hours, the stiffness of the dough was appreciably lowered, about 2.6% absorption under the control. The doughs containing a constant percentage of malt have a maximum variation of 1.87%, caused by increasing the H-ion concentration, while the fermentation period was constant. These changes are no doubt brought about by enzymes of the malt, chiefly the protease, but the others may likewise contribute to some extent.

In Table I it was pointed out that the flour under consideration could be developed mechanically; in Table II a development by the addition of acids was shown; and in Table III development by the addition of an oxidizing and bleaching agent was shown. It is therefore interesting to see whether this flour could be de-

veloped by increasing the enzymatic activity by the addition of malt, using the hand-mixing method. The same formula was used as in the previous tests referred to, with the addition of malt as shown in Table VII. Thus, by the addition of a 35 degrees Lintner malt, we have secured development on this flour and improvement over the control.

TABLE VII

DEVELOPMENT BY INCREASING ENZYMATIC ACTIVITY BY THE ADDITION OF MALT

Loaf No.	Mixed by	Time of mixing	Proof period	Volume	Volume	Malt	Score of bread
		min.	min.	cu. in.	%	%	
1	Hand	4	55	28.5	..	0.0	Very poor, no development
2	"	4	55	29.0	..	0.0	No development
3	"	4	55	31.0	7.9	2.0	Good
4	"	4	55	31.5	9.7	2.0	"
5	"	4	55	31.3	8.9	3.0	"

Turning our attention to Table VIII, we have a comparison of each of these forms of development, namely, mechanical, chemical, and enzymatic, compared with the control, all being mixed by machine. None of the loaves treated with acid, oxidizing agents, or malt showed as great an increase in volume as was obtained with various types of development by hand-mixing methods. In these remarks on the bread it has not been the intention to distinguish between the fine points of the loaves, but in a more general way to group the loaves into classes according to development or lack of development.

TABLE VIII

DEVELOPMENT BY OXIDIZING AGENTS, ACIDS, AND MALT, IN DOUGHS MIXED BY MACHINE

Loaf No.	Mixed by	Time of mixing	Volume	Increase in volume	Ingredient added	Score of bread
		min.	cu. in.	%		
1	Machine	18	32.0	Control	..	Good
2	"	18	31.7	"	..	"
3	"	18	32.5	2.2	0.001 gr. $KBrO_3$	Slightly better than Nos. 1 and 2
4	"	18	33.0	3.7	0.001 " "	Better than Nos. 1 and 2
5	"	18	32.6	2.5	0.1 gr. tartaric acid	Slightly better than Nos. 1 and 2
6	"	18	32.3	1.6	0.1 " "	Slightly better than Nos. 1 and 2
7	"	18	32.9	3.5	3 gr. malt	Better than Nos. 1 and 2
8	"	18	32.8	2.5	3 " "	Better than Nos. 1 and 2
9	"	18	33.4	5.0	½ " yeast food	Slightly better than Nos. 1 and 2
10	"	18	33.3	4.7	Bleached at mill	Slightly better than Nos. 1 and 2

The points that I wish to make are (1) that bread can be made from untreated flour by mechanical methods, (2) when treated with the proper chemicals, bread can be made with a minimum of mechanical development, and (3) that when enzymatic activity is increased but properly controlled, an improvement will likewise result with a minimum of mechanical or chemical treatment. Further, when mechanical mixing is greatly increased, the improvement caused by the addition of the various chemicals and enzymes is not so great as when compared under a minimum of mechanical development.

Thus, when we consider the hydrogen-ion concentration, it is necessary that all the facts concerning the flour, dough, or bread be taken into consideration. For instance, flours have been encountered which were overtreated with oxidizing agents, and baking tests demonstrated that good bread could be obtained only by using a very short fermentation, namely, 1½ hours. Any increase in time or any large increase in hydrogen-ion concentration resulted in inferior bread. It seems that to some extent these forms of development are interchangeable and when a flour or dough has been treated to a great degree by any one of these methods it is not necessary so extensively to employ the other methods to produce development. In all probability this development depends upon the degree of dispersion, or hydrolysis, of the protein bodies which may be produced by the methods mentioned and possibly others.

The baking capacity of a great many flours or doughs is often impaired by extreme application of one or more of each of these types of development in an attempt to make an improvement. Thus far, with one exception, we have pointed out different forms of development produced with little change, if any, in H-ion concentration.

What information does the hydrogen-ion concentration or buffer value determination impart? Let us assume that it is possible to have three flours made from the same mill mix, and so milled that the only variable of the flour is the hydrogen-ion concentration and the buffer value. To be specific, we shall assign a 0.40 ash and 11.75 protein to all three flours. Flour 1 has an H-ion concentration of pH=6.1 and a buffer value of 2.1; flour 2, pH=5.5 and the buffer value =1.8; while flour 3 pH=5.5 and the buffer value = 1.5. Interpreting these data, we conclude that flour 1, under the same conditions, will require more fermenta-

tion than either flours 2 or 3, to arrive at the maximum bread volume. It is therefore said that flour 1 has a longer fermentation period than flours 2 or 3. Flour 2 will reach the maximum of bread volume in a much shorter time than flour 1, and is said to have a shorter fermentation period. Flour 3 has the same pH as flour 2 but a lower buffer value, which will still further shorten its fermentation period.

In fact, both flours 2 and 3 will easily lend themselves to bread production, for they will require a comparatively short fermentation period and it is probable that the mechanical mixing can be somewhat lessened. Other examples of hydrogen-ion concentration and buffer value could be cited, but this has been done in other papers.

Before proceeding further with this discussion, it is well to define what conditions cause bread to appear old. To the baker, bread appears old when small crater-like holes are in the crust and certain breaks show on the sides of the finished loaf. To the more scientific mind, it is when the strength of the gluten or proteins of the dough mass have been lessened to such an extent that they are unable to retain the increasing pressure of the gases, resulting in holes on the sides of the loaf and peculiar breaks, caused when the "spring" in the oven occurs.

Again, to the baker, age appears when we have a pale crust. Speaking more scientifically, it is when the sugars, to a large extent, have been destroyed by the action of ferments. As the pH of a dough is lowered, it has been shown that its extensibility is lessened. It may thus have a direct influence on the physical properties of the dough in promoting age. Again, the lowering of the pH will, without doubt, greatly increase the activity of the yeast and flour enzymes, thus increasing the rate of gas production and hence causing the doughs to appear aged. Age of a dough is greatly talked of, yet few have attempted either to define it or to measure it. In a paper which I read before this convention in 1925, it was pointed out that sponge doughs with a comparatively short fermentation period in the dough stage, say 15 minutes, did not produce bread having the appearance of age, tho the fermentation of the sponge be carried 13 hours. Examining more closely, it will be found that to a great extent the gases are expelled in the mixer from the dough made from the sponge and fresh flour. The addition of the fresh flour to the sponge will also result in a dough of a higher pH than the sponge itself, and it is only logical to assume that the rate of increasing gas pressure within the dough is

lessened and at the same time extensibility or strength of the dough has been increased by fresh flour, which accounts for the absence of the described signs of age on the sides of the loaf. Sugar and milk are also added at the dough stage. These carry a sufficient supply of sugars and the bread will not appear old according to the second corollary of our definition.

What does this mean in terms of hydrogen-ion concentration? It means that in judging the age of a straight dough bread, a baker notes the appearance of the sides of the bread and color of crust, then uses his sense of smell. What does the chemist do? Some note the physical appearance and resort to a hydrogen-ion determination. But how about the conditions when a baker judges the age of a sponge dough bread? The signs of holes and color of crust disappear, so that the sense of smell is the only aid the baker has, while the chemist turns to his pH determination.

It has been my privilege to have been associated with some highly trained bakers, and in a number of tests where a dozen or more loaves made by the sponge process, varying an hour apart, were placed before them, they were unable to place more than 50% in the order of their proper fermentation periods. The hydrogen-ion determination placed each in its proper place. With straight doughs, it is much easier to determine age by inspection, but the pH determination will be found a useful index.

The pH or buffer value of the flour blend in some bakeries remains surprisingly constant. For a period of approximately six months I found very little difference in the buffer value or pH of the blend of a large bakery. Some mills also have been found to produce very uniform products in this respect. Each type of bread likewise had a pH which varied little. This is not to be marvelled at, for in the most modern of commercial bake shops, conditions of control are as precise as in many laboratories. Suppose that you regularly receive bread from some distant bakery, and you report to this bakery any information or change in their product. Having the record of such a bakery before you, samples are submitted that are under the standard for this plant. The pH is determined and no change has occurred. The small sample of the flour blend that was submitted with the samples likewise shows no change. What does it mean? To some, it means that there is very little to this determination called hydrogen-ion, or buffer value. To others it means that the fermentation and rate of increase in hydrogen-ion concentration of this dough has been normal. It suggests that the trouble has occurred by one of those

factors that does not affect the hydrogen-ion concentration. Perhaps the mechanical mixing, or some machine that handles the dough, is not functioning correctly, or again, some chemical that does not change the pH may be the cause of the trouble. Suppose that the sample does show a decrease in pH with no change in the flour blend; it would suggest that the temperatures or the yeast may have been increased through mistake, and if the samples continue to show this increase with no change in buffer value of the flour, it points to the fact that one or more of those factors that tend to overcome the buffer value of the dough has been changed. We would advise that the temperature, fermentation period, yeast, etc. be investigated. Should the change occur in only a few loaves, it would suggest that some of the dough may be staying in the machines or on the benches longer than necessary.

The color of bread, as a rule, becomes much whiter as the pH is lowered. Should the pH of the bread be raised by the addition of an alkaline reagent, the color begins to take on a creaminess which increases as the pH is increased. This color change is general in most all bakery products. In cakes, biscuits, and pastries, a baking powder having an alkaline end reaction gives a creamy cast to the baked product, while with a neutral one the creaminess disappears, and with a slightly acid baking powder, a whiter color results. Very remarkable increases in the whiteness of the crumb color of bread can be obtained by use of a sponge dough. This is due to the action of the acids in the absence of the salt. It is certain that in very acid sponges the gluten is in a highly dispersed condition. On most bakery products pH determinations assist in obtaining a desired crumb color.

The flavor and taste of bread are so important that some bakers produce products in which they give these points paramount importance. If a series of doughs have their pH adjusted by the addition of acid and an alkaline reagent, such as lactic acid and sodium carbonate, so that on coming out of the mixer, they range between pH 5.10 and pH 7.6, and are given a normal fermentation period, it is found that there is a great variation in flavor and taste. On the one hand is the sharp strong fermentative flavor, while at the other extreme the bread may even approach an alkaline or biscuit flavor.

In a commercial bake shop, the control of temperature has been of assistance in obtaining desired flavors. If a temperature between 70° and 80° F. with an average fermentation period and formula is used on a flour of pH 6.1, bread having a high

pH, for example pH 5.7, is produced. This is a very "young" type of bread with a "sweet" flavor. It has been my experience in many plants that it is almost impossible to produce this "sweet" flavor if the pH is appreciably lowered. The lowering of the pH is usually caused by increasing temperatures. This frequently happens in the summer when sufficient refrigeration is not obtainable.

As a parting thought, it is not the optimum of pH 5.0 for bread production that must be so constantly kept in mind in the commercial production of bread, but that there are different types of bread that have an optimum of their own. For example two extreme types will be considered: (1) bread having a volume of 5.4 cubic inches for every ounce of dough scaled; and (2) on the other extreme is the bread having a volume of 7.0 cubic inches per ounce of dough scaled. Why must the production chemist keep such in mind when it is not so essential to the academic chemist? Considering the first type of bread, the volume is exceedingly small, yet uniformity must be maintained. To choose a flour of high protein and low pH and buffer value, for example pH 5.4, is not wise. In many shops this would produce a dough so near the optimum of maximum volume, namely, pH 5.0, that it would be very hard to keep the volume low enough. A wiser choice would be a flour of much higher pH and buffer value, as it would tend to maintain both a low volume and good flavor. In fact, it is often desirable to lower the protein percentage in flour for such a bread. Should the "sweet" flavor above described, not be desired, a very low protein flour can be used and the pH of the bread brought to the optimum so familiar to all—pH 5.0.

If the second type of bread, having a volume of 7.0 cubic inches per ounce of dough, be desired with as sweet a flavor as possible, it would be desirable to employ flour with a lower pH or buffer value, namely pH 5.50. However, it must not be assumed that a flour with a pH of 5.50 is the best to use for all bread having this volume. Some desire that bread should have a very large volume and strong fermentative flavor. In this case it would not be wise to choose the flour with so low a pH unless its buffer value was high, but one with a considerably higher pH and buffer value.

Last, but not least, is the assistance rendered in the control of *Bacillus mesentericus* by the proper hydrogen-ion concentration.

I have suggested some of the ways by which hydrogen-ion concentration and buffer value determinations have been of assistance to some chemists and bakers. Their value to you depends upon your experience and skill in applying them to production problems in the bake shop.

BOOK REVIEW

Bread Baking, by M. H. Joffe, B.Sc. Published by The Colonial Salt Company, Akron, Ohio

Although the baking of bread is one of man's oldest industries, until comparatively a few years ago, it was an art. The skillful artisan passed what information he possessed on to his tyros, and altho he may have been a master of the technic of baking, few, if any, of the reasons for the various manipulations were known to him. Today, the process of bread making has ceased to be an art and has become a scientific industry. Few industries present so complex a problem. A fundamental knowledge of the raw materials used, their action in the dough, and the mechanical details of the equipment of the bakeshop are all essential to success. In this little book, the author deals with the question of the composition and action of each of the raw materials in a very clear and lucid manner. His chapter on bakery equipment is good and up-to-date. In the chapter devoted to bakeshop practice, the discussion of methods is ably treated and several characteristic formulas are given for the more common types of bread turned out by the modern bakery. The chapter on bread faults contains material which every one interested in bread making and judging should master. The subject of plant efficiency is also discussed and adds to the completeness of the discussion. A short chapter on the food value of bread by Miss Jean K. Rich, and a discussion of salt and its manufacture have been added. The book as a whole is simple and compact, and should find a ready reception on the part of both practical bakery operators and those interested in the more scientific side of the industry.

J. A. Dunn

VARYING CHARACTERISTICS OF THREE TYPES OF WHEAT GROWN UNDER THE INFLUENCE OF IDENTICAL ENVIRONMENT

II. The 1926 crop

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The Larabee Flour Mills Company, Kansas City, Mo.

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The results reported (Herman, 1926) on three pure type samples of hard winter wheat of the 1925 crop grown under identical conditions, indicated such marked variations in both analytical data and baking characteristics, that it was decided to study the intravarietal characteristics through additional crop years.

Pure strain samples of Kanred (Kansas number 2401, C. I. number 5146), Kharkof (Kansas number 382, C. I. number 6206), Turkey (Kansas number 570, C. I. number 1558), and Blackhull (Kansas number 343, C. I. number 6251) of the 1926 crop and seeded from the wheat as represented in the original communication of this series (Turkey not included in previous data) were obtained through the courtesy of S. C. Salmon, Professor of Agronomy of the Kansas State Agricultural College. These samples, as in the case of those from the 1925 crop, were grown under identical tillage, climatic, and soil conditions, on the experimental plots of the State Agricultural College; and, like those of the previous communication, are not to be considered as typical of either the crop or the type of wheat.

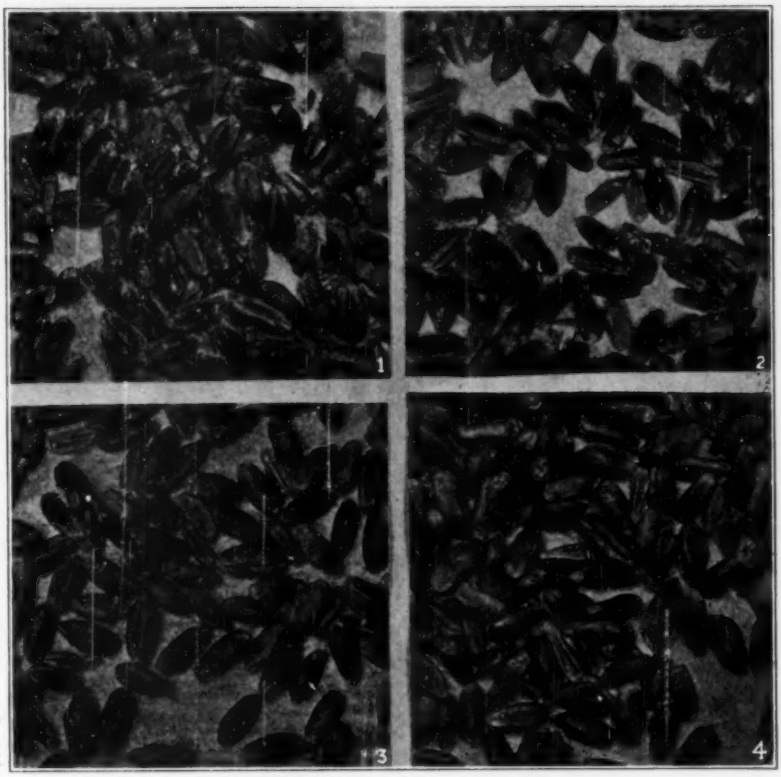
The sample of Turkey indicated a slight tendency toward yellow berry, carried some shriveled grains, and was slightly musty. (It had been shocked damp.) The Kharkof and Kanred samples also carried a considerable number of shriveled grains. The Kanred berries had a tendency towards the shoe-peg form, while the Blackhull berries were quite plump and well formed, and more uniform in character. The wheats are illustrated in Figure 1.

Weighed quantities of each variety were passed twice over a miniature milling separator and scourer. The weight per bushel before and after cleaning is given in Table I.

TABLE I

WEIGHT PER BUSHEL BEFORE AND AFTER CLEANING

	Kanred	Kharkof	Turkey	Blackhull
	lb.	lb.	lb.	lb.
Before cleaning	57	56.5	58.0	61.5
After cleaning	60	60.5	61.5	64.0



1. Kanred
2. Kharkof
3. Turkey
4. Blackhull

Fig. 1. Samples of Wheat Used in Experiments

The Blackhull sample had decidedly the highest weight per bushel and the Kanred sample the lowest.

The quantity of screenings per 3000 grams of wheat is given in Table II.

TABLE II

SCREENINGS PER 3000 GRAMS OF WHEAT

	Kanred	Kharkof	Turkey	Blackhull
	gm.	gm.	gm.	gm.
Screenings	36.6	22.9	19.0	12.5

The Blackhull sample carried the smallest amount of screenings while the Kanred sample carried the largest. This bears a direct relationship to the weight per bushel of the cleaned grain.

The analytical data on the wheat (after cleaning) are given in Table III.

TABLE III

ANALYTICAL DATA ON WHEAT AFTER CLEANING

	Kanred	Kharkof	Turkey	Blackhull
Moisture %	11.48	11.68	12.4	11.96
Ash %	1.68	1.74	1.76	1.68
Ash calculated to 13.5 per cent moisture, %	1.64	1.71	1.74	1.65
Protein (n x 5.7) %	13.65	13.25	13.33	11.82
Protein calculated to 13.5 per cent moisture, %	13.36	13.0	13.20	11.62
Initial pH *	6.559	6.644	6.610	6.627
Buffer pH †	4.852	4.818	4.903	4.801
Viscosity without acid (A‡)	86	98	103	62
Viscosity with acid (B)	158	170	171	103
B − A	72	72	68	41
Increase over B with H_2O_2	134	135	89	79

*Determination made on extract prepared by adding 100 cc. of distilled water to 10 grams of the finely ground meal. Extraction period one hour at 25° C., with occasional shaking. Bailey (1920) electrode, saturated calomel cell, type K Leeds and Northrup potentiometer.

†Determination made on same extraction with the addition of N/5° lactic acid in the proportion of 2.5 cc. of acid to 25 cc. of the centrifuged extract.

‡Following methods described by Durham, 1925.

The moisture content of the sample of Turkey was slightly higher than that of the other samples. The ash content varied some, being practically the same in Kanred and Blackhull, while Turkey showed a slightly higher range than Kharkof. The protein content was nearly the same in Kanred, Kharkof, and Turkey, with Blackhull practically 1.5 per cent lower. A close relationship existed as regards hydrogen-ion concentration expressed as pH, while a considerable variation in viscosity was indicated, particularly in the relationship of Blackhull and the other wheats of the series.

Aside from the protein content and viscosity measurements, there were no pronounced variations in the wheats to indicate marked differences in desirability from an analytical standpoint.

Preparatory to milling, the samples were tempered for definite periods in sealed tin containers. The amount of water used was calculated from the moisture content of the wheat. The samples were milled on an Allis experimental reduction unit, the flow being similar to that maintained for previous work. Each sample was handled on the breaks six times, and the patent flour represents the throughs of the 11xx cloth. The samples were milled in duplicate to insure greater accuracy in interpretation of results and were handled under strictly comparable conditions. The milling data are given in Table IV.

TABLE IV

MILLING DATA ON TEMPERED CLEANED WHEAT

	Kanred	Kharkof	Turkey	Blackhull
Yield	4 bu. 53 lb.	4 bu. 51 lb.	4 bu. 51 lb.	4 bu. 53 lb
Extract per cent patent	55.4	56.7	55.7	55.4
Patent flour, per cent	82.8	83.8	82.4	83.0
Temper, hours	20	20	20	18
Color of flour*	BrLtC	BrLtC	BrLtC	BrLtCW
Dress	Good	Good	Good	Good
Roll wheat moisture, per cent	15.7	15.7	16.0	15.7

*Key to grading: Br=bright, Lt=light, C=creamy, V=very, sl=slight, sp=spherical, el=elongated, Bl=blown.

Owing to the character of the wheat, the Blackhull sample was tempered for two hours less time than the other samples. The milling yield was relatively high for all samples, being especially high for Blackhull when considered in relation to the weight per bushel of the wheat. The per cent extract patent (calculated by dividing the sum of the total products into the patent flour) was highest for Kharkof, and again was especially low for Blackhull in relation to the latter's weight per bushel. The percentage of patent varied but 1.4% on the four samples, being highest for Kharkof and lowest for Turkey. In relation to test weight, Kharkof carried the best milling characteristics, with Kanred next, then Turkey, and finally Blackhull.

The Kanred bran was broad and thin, and cleaned easily. The middlings particles were rather small, but sharp and bright.

The Kharkof bran was very broad and thin, and was slightly more difficult to clean than the Kanred. The middlings particles were relatively small, sharp, and bright.

The Turkey bran was small and thin, and cleaned easily. The middlings particles were relatively small, sharp, and bright.

The Blackhull bran was broad and thick, but cleaned easily. The middlings particles were large, bright, and somewhat softer than those from the other samples.

The characteristics indicated by this particular sample of Blackhull are in line with the observations on this type of wheat reported by Swanson, Working, and Oakes (1926)

The analytical data covering the patent flour milled from each variety, are given in Table V.

TABLE V

ANALYSIS OF UNBLEACHED PATENTS

	Kanred	Kharkof	Turkey	Blackhull
Moisture,	13.26	13.16	12.66	12.76
Ash, %	0.405	0.440	0.440	0.415
Ash calculated to 13.5 per cent moisture, %	0.404	0.438	0.436	0.412
Protein (N x 5.7) %	11.98	11.30	11.50	10.62
Protein calculated to 13.5 per cent moisture, %	11.92	11.29	11.40	10.53
Initial pH	6.32	6.34	6.22	6.13
Viscosity with acid (A)	335	301	313	227
Viscosity with acid plus H_2O_2 (B)	405	413	446	285
B-A	70	112	132	58

The Kanred sample carried the lowest ash content while the Kharkof and Turkey samples were practically identical. These results are very close when interpolated to the same yield and percentage patent basis.

The protein content of the patent flours followed anticipated spread in relation to the protein content of the wheat.

The viscosity measurements indicate marked variations but do not compare strictly with the viscosity data obtained on the wheat suspensions.

The hydrogen-ion concentration expressed as pH showed a considerable spread between the Blackhull and Kharkof samples, being lowest for the Blackhull.

As in the original communication a series of test bakings was made extending over a period of two weeks, employing the Werner (1926) method with certain modifications, essentially as regards methods of handling the dough and type of baking oven employed. The formula used, with the indicated exception, follows: Flour, 100 grams, sugar, 2.5 grams, salt, 1.0 gram, yeast, 3.0 grams, and distilled water. The doughs were all mixed by hand for a definite length of time, with no variations as regards temperature or proofing time but with variations in fermentation period, as indicated. All bakings were in duplicate. Loaf volumes were measured at a definite time from the oven in an accurately calibrated seed-displacement loaf-measuring device, using white mustard seed.

The data covering the first series, using a fermentation period of 2:40 hours, are given in Table VI, and the loaves are illustrated in Figure 2.

A difference in absorption of 0.5 per cent was evident on the doughs, the lower figure being on the Blackhull. This particular dough, in contrast to the other three, softened during fermentation and "slacked off" to a marked degree.

TABLE VI

EXPERIMENTAL BAKING DATA COVERING UNBLEACHED PATENTS ON 2:40 HOURS FERMENTATION

	Kanred	Kharkof	Turkey	Blackhull
Absorption, %	66.5	66.5	66.5	66
Temperature during fermentation and proofing, °F.	80	80	80	80
Fermentation period, hr.	2:40	2:40	2:40	2:40
Proofing period, hr.	1:00	1:00	1:00	1:00
Crumb color*	BrLtC	BrLtC	BrLtC	VBrLtC
Grain score and character	99.9 sl sp	99.9 sl sp	99.9 sl sp	99.8 sl sp
Volume, cc.	440	440	430	410
Character of loaf	Bold	Bold	Bold	Bold –

*See footnote to Table V.

Kanred Kharkof Turkey Blackhull

Fig. 2. Loaves with 2:40 Hours Fermentation Period

The crumb color was very similar on Kharkof, Kanred, and Turkey, while Blackhull was considerably brighter and whiter. The grain structure was slightly inferior on all the loaves of the series, being decidedly spherical in character. The loaf volume was identical on the Kanred and Kharkof samples, slightly less on the Turkey, and rather limited on the Blackhull.

In order to determine the reaction of the flours to oxidizing agents, the samples were next baked on the same fermentation period, with the addition, however, of 0.5% Arkady to the doughs. The data from this baking are given in Table VII, and the loaves are illustrated in Figure 3.

TABLE VII

EXPERIMENTAL BAKING DATA COVERING UNBLEACHED PATENTS ON 2:40 HOURS FERMENTATION WITH THE ADDITION OF 0.5 PER CENT ARKADY TO THE DOUGHS

	Kanred	Kharkof	Turkey	Blackhull
Absorption, %	67.0	67.0	67.0	66.5
Fermentation period, hr.	2:40	2:40	2:40	2:40
Proofing period, hr.	1:00	1:00	1:00	1:00
Temperature during fermentation and proofing, °F.	80	80	80	80
Crumb color*	BrLtC	BrLtC	BrLtC	VBrLtC
Grain score and character	100 sl sp	99.9 sp	99.9 sp	99.8 sp
Volume, cc.	490	435	435	430
Character of loaf	Bold	Bold	Bold	Bold

*See footnote to Table V.

As in the first baking, a difference of 0.5% in absorption was evident, with the lower figure on the Blackhull. This particular dough likewise again slackened during fermentation.

Kanred Kharkof Turkey Blackhull

Fig. 3. Loaves with 2:40 Hours Fermentation Period, with Arkady

The crumb color was practically identical on Kanred, Kharkof, and Turkey, with Blackhull the brightest and whitest of the series.

The reaction of these flours to the influence of an oxidizing agent as regards loaf volume, grain structure, and external appearance, is interesting. Kanred showed a pronounced positive reaction as regards both loaf volume and grain structure (volume increasing 50 cc.) while the loaf volume of Kharkof and Turkey remained practically the same, with Blackhull showing a positive reaction of 20 cc.

The grain structure was improved on all loaves of the series, Blackhull again having the least desirable character while Kharkof and Turkey were practically identical and slightly inferior to Kanred.

All the loaves of this series carried a bolder external structure than those in the preceding series.

The samples were again baked on the original formula, employing, however, a fermentation period of 4 hours and 30 minutes. The data from this baking are given in Table VIII, and the loaves are illustrated in Figure 4.

TABLE VIII

EXPERIMENTAL BAKING DATA COVERING UNBLEACHED PATENTS ON 4:30 HOURS FERMENTATION

	Kanred	Kharkof	Turkey	Blackhull
Absorption, %	66.5	66.5	66.5	66
Fermentation period, hr.	4:30	4:30	4:30	4:30
Proofing period, hr.	1:00	1:00	1:00	1:00
Temperature during fermentation and proofing, °F.	80	80	80	80
Crumb color*	LtC	LtC	LtC	BrLtC
Grain score and character	101	101 Bl	101 Bl	101
Volume, cc.	335	325	325	320
Character of loaf	Irregular	Irregular	Irregular	Irregular

*See footnote to Table V.

The absorption was 0.5% lower on this series also, on the Blackhull, and this particular dough again slackened off during fermentation.

Kanred Kharkof Turkey Blackhull

Fig. 4. Loaves with 4:30 Hours Fermentation Period

All the loaves of this series carried pronounced shell tops, and the loaf formation was very irregular. The loaf volume was much limited and indicated a variation of but 15 cc. between the largest loaf (Kanred) and the smallest loaf (Blackhull) of the series.

The grain structure was very tight and thin except for a conspicuous break-down on Kharkof and Turkey, and only a slight break-down on Kanred and Blackhull.

The relationship as regards crumb color was comparable with the preceding data, but the crumb color was inferior to that obtained on the loaves baked from doughs fermented for a shorter period.

The samples were next baked on a commercial type sponge formula,[1] maintaining a variable fermentation time (calculated from the time required for the sponges to "break") with a definite dough, bench, and proofing period. The doughs were otherwise handled the same as in the previous series. The data from this series are given in Table IX and the loaves are illustrated in Figure 5.

A slightly lower absorption was again evident for Blackhull, as was likewise the dough slackening tendency.

[1] Commercial type sponge formula:

Sponge	Dough
Yeast 2%	Sugar 2%
Arkady 0.5%	Sweet condensed milk 6%
	Salt 1.75%
	Lard 1.75%
	Malt 1.0%

TABLE IX
EXPERIMENTAL BAKING DATA COVERING UNBLEACHED PATENTS USING COMMERCIAL TYPE SPONGE FORMULA

	Kanred	Kharkof	Turkey	Blackhull
Absorption, %	67	67	67	66.5
Sponge time, hr.	4:49	5:06	5:00	4:37
Dough time, hr.	:15	:15	:15	:15
Bench time, hr.	:10	:10	:10	:10
Proofing period, hr.	1:00	1:00	1:00	1:00
Temperature during fermentation and proofing, °F.	80	80	80	80
Crumb color*	BrLtCW	BrLtCW	BrLtCW	BrLtCW+
Grain score and character	100 el	100−sp	100 sp	99.9 sp
Volume, cc.	470	460	455	470
Character of loaf	Bold	Bold	Bold−	Bold

*See footnote to Table V.

Kanred Kharkof Turkey Blackhull

Fig. 5. Loaves baked by Commercial Type Sponge Formula

The spread in fermentation period, as calculated from the time required for the sponge to break, amounted to 29 minutes between Kharkof and Blackhull. All the loaves were quite bold, but especially Kanred and Blackhull. The loaf volume indicated a spread of but 15 cc., being highest for Kanred and Blackhull and practically the same for Kharkof and Turkey. More variation in grain structure was evident between the loaves in this series, being distinctly inferior on the Blackhull and superior on the Kanred. The relationship as regards crumb color was maintained as in the previous series, but was naturally less pronounced, owing to the type of formula used.

In order to determine the action of these samples on a short fermentation period, they were again baked on the original formula, employing a fermentation period of but 2 hours. These data are given in Table X, and illustrated in Figure 6.

The slightly lower absorption and softening dough action of the Blackhull sample evident on the previous series was again indicated.

TABLE X
EXPERIMENTAL BAKING DATA COVERING UNBLEACHED PATENTS ON A 2-HOUR FERMENTATION PERIOD

	Kanred	Kharkof	Turkey	Blackhull
Absorption, %	67	67	67	66.5
Fermentation period, hr.	2:00	2:00	2:00	2:00
Proofing period, hr.	1:00	1:00	1:00	1:00
Temperature during fermentation and proofing, °F.	27°C	27°C	27°C	27°C
Crumb color*	BrLtC	BrLtC	BrLtC	VBrLTC
Grain score and character	100 sl sp	100 sl el	100 sl sp	100 —sp
Volume, cc.	440	435	430	425
Character of loaf	Sl ragged	Sl ragged	Sl ragged	Fair

*See footnote to Table V.

The loaf volumes were relatively uniform, with the Kanred slightly the largest and with the other loaves of the series practically the same. The grain structure was slightly better for Kharkof and poorest for Blackhull. The crumb color was again better for Blackhull. The Kanred, Kharkof, and Turkey loaves were slightly ragged, while the Blackhull loaves were well formed.

Kanred Kharkof Turkey Blackhull

Fig. 6. Loaves with 2 Hours Fermentation Period

Discussion and General Comparative Summary

The influence of identical soil type, tillage, and climatic conditions was not constant on the true type varieties of wheat of the 1926 crop grown from the seed wheat represented in the original communication of this series, as regards physical characteristics, analytical data, and milling and baking characteristics.

The weight per bushel of the cleaned Blackhull wheat was identical in both crops, while the seed wheat of Kharkof and Kanred weighed 2.5 pounds per bushel heavier.

The moisture content of the wheat of the 1926 crop was 2.12% higher for Kanred, 1.66% higher for Kharkof, and 2.58% higher for Blackhull.

The ash content of the wheat of the 1926 crop (calculated to a 13.5 moisture basis) was 0.22% for Kharkof and Blackhull and only 0.01 higher for Kanred.

A decrease in protein content of the 1926 crop from the seed wheat was indicated, Kanred dropping 3.41%, Blackhull 3.63%, and Kharkof only 0.38%.

The initial pH and buffer pH determinations also indicated a change, but were erratic in both degree and direction, being 0.051 higher for Kanred, 0.084 lower for Kharkof, and 0.117 lower for Blackhull. The buffer values were higher on all wheats of the series, from the 1926 crop.

The relative viscosity measurements did not vary over an extremely wide range. As relating to the phase covered by "the increase over B with hydrogen peroxide," the 1926 crop samples gave slightly higher readings; Kanred showed an increase of 4 points, Kharkof an increase of 15 points, and Blackhull an increase of 20 points.

The milling yield was excessive for all three samples from the 1926 crop, Kanred requiring 9 more pounds on a barrel basis, Kharkof 3 more pounds, and Blackhull 7 more pounds.

The percentage extract patent was practically the same for Kanred and Blackhull on the two crops, while it was 1% higher on Kharkof from the 1926 crop. A higher percentage of patent was obtained on all wheats of the 1926 crop, being 2.3% higher for Kanred, 1.7% higher for Kharkof, and 2.6% higher for Blackhull.

The ash content of the patent flours (calculated to a 13.5% moisture basis) was higher on the wheats from the 1926 crop. Kanred indicated an increase of 0.014%, Kharkof an increase of 0.048%, and Blackhull an increase of 0.042%.

The patent flour from the 1926 crop, as anticipated from the wheat, indicated a lower protein schedule, dropping 3.73% for Kanred, only 0.61% for Kharkof, and 3.40% for Blackhull.

A lower spread was likewise evident as regards initial pH on the patent flours of the 1926 crop, being 0.34 lower on Kanred, 0.41 lower on Kharkof, and 0.30 lower on Blackhull. In this connection attention is called to the fact that the initial pH was highest on the Blackhull samples for both crops. This is in line with unpublished data covering the relation of initial pH of patent flour to initial pH of wheat of definite types.

The relative viscosity measurements, as relating to "B - A" was higher on all samples of the 1926 crop, increasing 18 points on Kanred, 34 points on Kharkof, and 16 points on Blackhull.

The baking data on the two crops are strictly comparable, from a method and procedure standpoint, with the exception of a variation in fermentation period of 15 minutes on the first two

series; the 1925 crop having been handled on a 15-minute longer time.

The absorption on the three varieties was more uniform for the 1926 crop. From the 1925 crop, the Kanred sample consistently carried over 2.5% higher absorption than the Kharkof and the Blackhull. Blackhull from both crops had the lowest absorption. The variation in absorption on varieties from the 1926 crop were not sufficient to be translatable into commercial operations.

As regards comparative loaf volume from the two crops, there was a consistent decrease in volume for the varieties from the 1926 crop in both the initial baking series and the series carrying an oxidizing reagent. In the first series the Kanred from the 1926 crop was 60 cc. or 12% lower, the Kharkof was 10 cc. or 2.2% lower, while the Blackhull was 35 cc. or 7.8% lower. On the second series, with an oxidizing agent, the Kanred from the 1926 crop was 25 cc. or 4.8% lower, the Kharkof was 40 cc. or 8.4% lower, while the Blackhull was 20 cc. or 4.4% lower.

In relation to the reaction of oxidizing reagents on loaf volume, no consistent effect existed. The Kanred from the 1926 crop indicated a positive reaction of 50 cc. and on the same variety from the 1925 crop, only 15 cc. Kharkof of the 1926 crop carried a negative reaction of 5 cc., while the sample from the 1925 crop indicated a positive reaction of 25 cc. The Blackhull of the 1926 crop gave a positive reaction of 20 cc., while that of the 1925 crop gave a positive reaction of but 5 cc.

In a comparison of loaf volume on the two crop samples, handled on a fermentation period of 4:30 hours, the volumes were identical for Kanred, 3% lower for Kharkof, and 5% higher for Blackhull.

The grain structure and grain character were distinctly superior for the samples from the 1925 crop.

As regards flour color as well as crumb color, the Blackhull samples from both crops were whiter than those from the other varieties.

Summary

Results of experimental milling and experimental baking tests are given, as well as analytical data covering wheats and patent flours representing four pure-type varieties of hard winter wheats grown under identical environment. The general characteristics of these wheats are also compared with the seed wheat representing three of the same varieties of the previous crop.

From a physical examination, the Blackhull sample was the most desirable, while from an analytical standpoint there were no pronounced variations aside from the protein content and the viscosity measurements, which were in favor of Kanred.

The milling qualities were practically the same as regards yields and percentages, with Kharkof slightly more desirable. The middlings and bran were similar in character on Kanred, Kharkof, and Turkey, while the Blackhull middlings particles were larger and softer and the bran was decidedly thicker.

The grain structure, particularly of all loaves baked under the fixed method, was inferior to the normal, while under the same methods, Kanred consistently produced loaves of the largest volume, and Blackhull loaves of the lowest volume. When a sponge of a commercial type was mixed and fermentation time was varied, the loaf volume varied 3.1% between the varieties, being highest and identical for Kanred and Blackhull.

The absorption of flour milled from Blackhull wheat was slightly less than that of the other flours, and likewise indicated tendencies toward slackening in the dough during fermentation in all the test bakes.

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A STUDY OF THE PHYSICAL PROPERTIES OF WASHED GLUTEN

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Introduction

The physical properties of gluten and their relation to the baking quality of wheat flours has been the subject of considerable investigation. On account of the complex nature of gluten and its susceptibility to change, the problem has always been an elusive one. The general weight of opinion formed from these investigations has been that gluten quality is an important factor in baking.

This paper presents data on this problem which were obtained by a method of attack different from any previously used to any degree, so far as we are aware. Our method consists in measuring certain physical properties of washed gluten by means of a mechanical device. Altho the measurement showed other properties, in this paper we are concerned chiefly with the property which varies most obviously, that is, the force required to extend the gluten to the breaking point.

Method of Measurement

After considerable experimenting a machine was designed which measured, and recorded in the form of a graph, the force required to extend the gluten and the distance extended. The breaking point is shown by a sharp change in the direction of the line. The form of the curve indicates the elasticity of the gluten, or how near the gluten comes to obeying Hooke's law. With perfectly elastic substances, within their elastic limits, the distance extended is directly proportional to the force applied.

The machine operates on a thin layer of gluten, as shown in Figure 1. This layer is stretched by the ball point (b) moving at a constant speed of 10 cm. per minute and the force required and the distance extended are recorded by the arm (a). The distance is recorded in centimeters and the force in grams.

Samples tested were prepared from 1.5 grams of washed gluten and rounded into as perfect a ball as possible. They were then allowed to stand for 10 or 12 hours in water at 15° C. They were removed from the water, pressed between the plates by the device which blanks

off the holes in the plates, and tested immediately. The tests, almost without exception, were made in duplicate by using two pieces of the same gluten. While tests of this nature are not infallible, the average variation of duplicates being about 5%, nevertheless it was possible to learn much of value about the gluten.

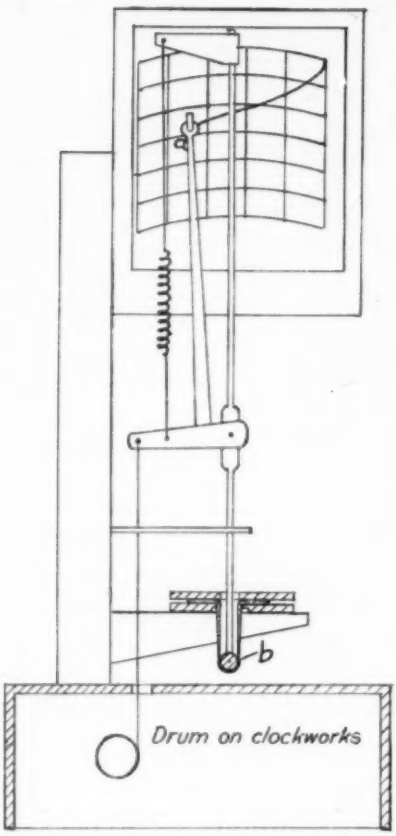

Fig. 1. Gluten Testing Machine

Method of Washing

The glutens were washed in moderately hard well water, the temperature of which ranged between 13° and 15° C. Ten grams of flour was used and allowed to stand for one hour in the dough before washing. The washing was thoroly done, but care was taken to recover as much gluten as possible. The excess water was pressed from the gluten before weighing.

Method of Baking

The following formula was used for the baking test.

	gm.
Flour	340
Sugar	10
Salt	7
Shortening	7
Yeast	7
Water	According to absorption.

The loaves were fermented in a box kept at 80° F. by thermostatic control, and were proofed at approximately 90° F. The hard white and blended flours mentioned, whether patent, clear, or straight, were given a first rise of 100 minutes, a second rise of 30 minutes, a third rise of 20 minutes, then rounded and moulded as usual. Hard red spring wheat patents, clears, and straights were given a first rise of 120 minutes, a second rise of 60 minutes, a third rise of 20 minutes. The loaves were baked about 30 minutes in an electric oven.

For samples of abnormal moisture content, enough flour was added to contain the same dry material as 340 grams of flour with normal moisture.

Variation in Character of Gluten With Variety of Wheat

Data for unbleached, freshly milled, straight-grade flours from a commercial mill are shown in Table I (See also Fig. 2).

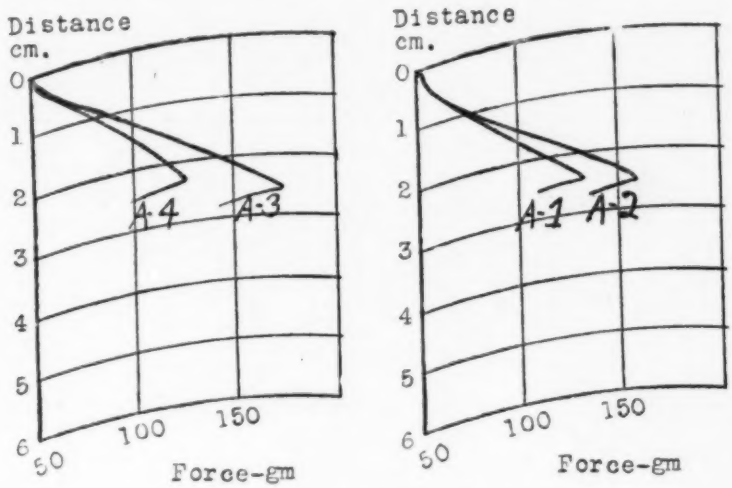

Fig. 2. Examples of Gluten Curves

TABLE I

EXAMPLES OF VARIATION IN GLUTEN QUALITY WITH VARIETY OF WHEAT

Sample	Protein, %	Ash, %
A-1 Washington hard white	12.5	0.49
A-2 Washington D. N. spring	13.0	0.47
A-3 Montana D. N. spring	13.3	0.50
A-4 Washington Club	8.6	0.46

Gluten data			
Sample	Force, g.	Distance, cm.	Loaf volume, cc.
A-1	130	2.4	2050
A-2	155	2.5	2240
A-3	170	2.5	2120
A-4	125	2.2	1560

Variation in Gluten Character of Patent and Clear

The data of Table II are for freshly milled unbleached samples taken from the commercial mill as before. Sample 1 is a short patent from a blend of 50% Washington hard white wheat and 50% Washington hard red; No. 2 is the clear from the same milling. Sample 3 is a very short patent from Montana hard red spring wheat and No. 4 is the clear. Sample 5 is a long patent from the same kind of wheat and No. 6 the short clear. Sample 7 is a medium patent from Washington hard white wheat and No. 8 the clear.

TABLE II
VARIATION IN GLUTEN QUALITY OF PATENT AND CLEAR FLOURS

Sample	Force, g.	Distance, cm.	Protein, %	Ash, %	Loaf vol., cc.
B-1	140	2.4	10.7	0.38	2320
B-2	120	2.5	12.9	0.78	1830
B-3	200	2.3	12.3	0.38	2390
B-4	130	3.0	15.4	0.68	1950
B-5	175	2.5	13.2	0.45	2220
B-6	85	3.4	18.0	1.55	2100
B-7	140	2.4	11.9	0.42	2090
B-8	60	2.6	15.2	1.13	1420

The gluten in the clear invariably requires less force to extend it than that in the patent, while the distance extended before breaking is greater for the clear than for the patent. Decreasing the percentage of patent tends to increase the force required and decrease the distance stretched. Decreasing the percentage of clear has the opposite effect.

Effect of Grinding on Gluten Quality

Shollenberger and Coleman[1] thoroly investigated the effect of grinding on flour. Our experiments gave results in accord with their findings. The two samples used were of the same milling as B-5 and B-7. They were ground seven times through a small grinder with steel burr faces which were set up tight. The room was kept cold during the grinding and time was allowed to elapse between successive grindings so that the flour was always cool. The results appear in Table III.

TABLE III
EFFECT OF GRINDING ON GLUTEN QUALITY OF WHEAT

Sample	Force, g.	Distance, cm.	Loaf vol., cc.
C-1 Before grinding	140	2.5	2280
C-2 After "	150	2.4	2300
C-3 Before "	130	2.4	2150
C-4 After "	140	2.4	2160

The results show that little change occurs to the gluten by reducing it to a state of fine division, and if a small change took place as indicated it was probably due to oxidation by the air. Grinding with the rolls hot might increase the oxidation. Data which will be presented next show that considerable heat is required to change the gluten greatly.

Effect of Heat

Portions of samples C-1 and C-3 were placed in shallow pans, the layer of flour being about 3 cm. deep, on the hot plate of a Mojonnier moisture oven and the oven was kept at a certain temperature for 16

[1] Shollenberger, J. H. and Coleman, D. A. Influence of granulation on chemical composition and baking quality of flour. U. S. Dept. Agr. Bull. 1463 (1926).

hours. No vacuum was used and the moisture was allowed to escape by leaving a crack at the door opening. In Table IV appear data obtained from these experiments.

TABLE IV
EFFECT OF HEAT ON GLUTEN QUALITY

Sample	Temp., °C.	Force, g.	Distance, cm.	Loaf vol., cc.
		Hard red spring flour		
D-1	80	150	2.6	2190
D-2	95	270	2.3	2160
D-3	108	315	2.0	2080
D-4	120 passed	300* at	0.7	930
		Hard white flour		
D-5	90	210	2.5	2090
D-6	105	160	2.2	2130
D-7	120 passed	300* at	0.8	960

*Force too great to make complete measurement.

Other changes probably took place in the flour as well as alteration of the gluten. As shown by data presented later, the effect of heating on the gluten appears to be oxidation. Later data in this paper also indicate that the change in the gluten was perhaps responsible for the inferior baking qualities of flours heated to 120° C., compared with the fairly good baking results obtained with flours heated to 105° and 108° C. (See data on chlorination.)

Effect of Mill-Maturing Treatment

Samples B-1 to B-8 were taken after the mill-maturing treatment had been given. In Table V are given the results of tests made on the glutens of these samples. E-1 to E-8 are the corresponding samples. E-9 and E-10 are the short hard spring wheat clears.

TABLE V
EFFECT OF MILL MATURING TREATMENT ON GLUTEN QUALITY

Sample	Treatment	Force, g.	Distance, cm.	Loaf vol., cc.
E-1	1.5 g. NCl_3	205	2.1	2340
E-2	4.0 g. NCl_3	250	1.9	1980
E-3	1.0 g. NCl_3	240	2.3	2480
E-4	4.5 g. NCl_3	250	2.5	2350
E-5	1.0 g. NCl_3	230	2.5	2420
E-6	2.5 oz. Cl_2	190	2.7	2570
E-7	3.0 g. NCl_3	165	2.4	2500
E-8	1.7 oz. Cl_2	120	2.3	1730
E-9	none	100	2.9	2030
E-10	14.0 g. NCl_3	260	2.5	2500

In the mill-maturing treatments for the foregoing, the amount of oxidizing agent is sufficient to affect the gluten as well as the color of the flour. It will be seen that the general effect of oxidation is to

increase the force required to extend the gluten and to decrease somewhat the distance reached before breaking. In this regard experiments E-5, E-6, E-9, and E-10 show that the effect of chlorine is similar to that of nitrogen trichloride. More data on the effect of chlorine follow.

Effect of Chlorine

Chlorine was applied to the flour by the apparatus shown in Figure 3, and was furnished by bubbling air through 1:1 hydrochloric acid containing a small amount of potassium chlorate. The quantity of chlorine produced was determined by means of the following reactions:

$$2KI + Cl_2 \rightarrow 2\,KCl + 2I$$

$$2I + 2Na_2S_2O_3 \rightarrow 2NaI + Na_2S_4O_6$$

A thiosulphate solution of such concentration that 1 cc. was equal to 1 gm. of chlorine per barrel was prepared, and 10 gm. of potassium iodide per 100 cc. was added. Two methods were used to find the ratio of the stream divider. One was to place another bottle of thiosulphate and iodide so that both streams were bubbled through the solution. The other method was to place the iodide-thiosulphate solution in the rotating bottle and operate as tho flour were being treated. As soon as the color turned in one solution, the excess thio-sulphate in the other solution was titrated with chlorine water of known strength. The two methods of absorption proved to be substantially equal, and the average ratio of the stream divider was found to be 11:10. The divider is so arranged that the difference in back pressure, within certain limits, does not affect the results.

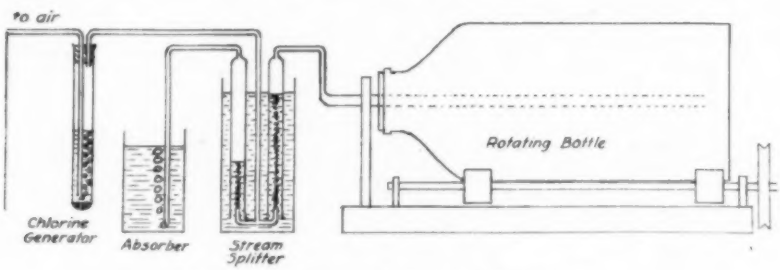

Fig. 3. Apparatus for Chlorine Treatment

Whether flour absorbs chlorine to the same degree as the solution, could not be readily determined, but we believe the absorption was fairly complete in both cases. At least, the quantity of chlorine required was not far different from commercial practice. Plenty of time was used in applying the chlorine, from 10 to 30 minutes being required to treat a charge of 400 grams of flour in the device.

Three types of flour were treated with chlorine. Sample F was a long patent from Montana hard red spring wheat, sample G was a high-grade clear from a similar wheat, and sample H a long patent entirely of hard white. The samples were obtained unbleached from the commercial mill. The results of the analysis of these flours are recorded in Table VI. The results of treating these flours with varying amounts of chlorine are shown in Table VII. The loaf volume is recorded as being the most practical measure of baking quality of gluten.

TABLE VI
ANALYSIS OF SAMPLES F, G, AND H

Sample	Moisture, %	Ash, %	Protein, %
F	13.3	0.45	13.2
G	13.3	0.69	15.6
H	12.8	0.44	11.7

TABLE VII
EFFECT OF CHLORINE ON SAMPLES F, G, AND H

oz. Cl_2 per bbl.	Gluten test		Loaf vol., cc.
	Force, g.	Distance, cm.	
	Sample F		
0.0	160	2.6	2140
0.25	170	2.6	2510
0.50	205	2.5	2650
0.75	205	2.3	2490
1.00	280	2.0	1440
1.50	270	1.1	1200
2.0	260	1.2	980
3.0 passed	300* at	1.1	1100
4.0 "	300* "	1.2	950
	Sample G		
0.0	135	3.0	1950
0.25	130	2.8	2240
0.75	205	2.8	2360
1.00	255	2.5	2250
1.50	240	2.1	2670
2.00	255	1.8	2080
2.50	245	2.1	1780
3.00	295	1.9	1370
4.00	250	2.2	1140
5.00 passed	300* at	1.2	1210
6.00 "	300* "	0.8	1130
7.00 "	300* "	0.8	980
	Sample H		
0.0	100	2.3	2010
0.5	120	2.4	2330
1.0	150	2.3	2330
1.5	150	2.3	2200
2.0	165	2.2	1880
3.0	210	2.2	1500
4.0	200	2.2	1410
5.0	135	2.5	1510
6.0	120	2.5	1640
7.0	170	2.1	1540

*Force too great to make complete measurement.

The amount of gluten recovered decreased as the degree of chlorination increased, but in no case was any difficulty encountered in obtaining a good yield of gluten. For sample F, the wet gluten fell from 36.0 to 32.8%; for sample G, from 43.5 to 36.2%. Sample H showed the least variation in this regard, going from 32.8 to 30.2%.

It will be seen that the general trend of the gluten character with increasing chlorination is to require more force to extend, but to shorten the distance extended before breaking. With hard white flour this is not so marked, but the comparison of the graphs for effect of chlorination on gluten quality shows that it is probable that further chlorination would cause a marked increase in the force. Several of the glutens for this series of experiments were washed and tested several times when irregularities appeared in the curve, and in two instances, as shown by dots on the curve, chlorination was repeated. We also have data on flour from a blend of nearly all hard white wheat which show a curve similar to that shown for the hard white here.

Altho the general trend of the gluten force curve is upward with increasing chlorination, all the curves show a point where more or less softening of the gluten takes place. In flours with which we worked, the softening point was too far removed from the point of maximum loaf volume to cause any trouble in commercial practice. However, considerable variation was shown in the distance of the softening point from maximum loaf volume, and it may be that in the case of some flours the softening takes place near enough to the maximum loaf volume to cause unexpected results on chlorination.

It appears also that it took more chlorine to change the gluten in the hard white flour than in the others, in spite of its low gluten content. Whether this is due to the chlorine attacking the starch of hard white flour more readily than that of hard red spring or to an inherent difference in the gluten, we have no proof to offer. We will show later, however, that the action of chlorine on the gluten is chiefly that of an oxidizing agent. The fact that more equivalents of chlorine than of nitrogen trichloride are required to change the gluten an equivalent amount (samples E-9, E-10, E-6, B-6; effects of mill-maturing treatment are evidence of this) tends to show that chlorine probably attacks the starch to a considerable extent. On the other hand, in the case of the mill-maturing treatments, the hard white wheat flour glutens showed a greater resistance to change than hard red spring wheat flour glutens when treated with nitrogen trichloride. The small amount of nitrogen trichloride required for the mill-maturing treatment makes it appear that this compound attacks the gluten without much being wasted on the starch.

Effect of Hydrogen Chloride

This work was done to establish the difference in the effect of treating flour with chlorine, and with an amount of hydrogen chloride equivalent to that liberated by the action of chlorine on the flour. Flour samples F, G, and H were used.

The hydrogen chloride was applied in the rotating bottle used for the chlorine treatment. The stream divider was not used in this case and instead of the chlorine generator a small amount of concentrated sulphuric acid in a test tube was used. Sufficient sodium chloride to produce the amount of hydrogen chloride desired was introduced into the test tube and the acid was gradually warmed as the air was bubbled through. This reaction was tested and found to be practically quantitative. The high affinity of hydrogen chloride for water and the slow rate of application made it probable that only a negligible quantity escaped from the flour. The results obtained appear in Table VIII.

TABLE VIII

EFFECT OF HYDROGEN CHLORIDE ON SAMPLES F, G, AND H

gm. HCl per bbl.	Gluten test		Loaf vol., cc.
	Force, g.	Distance, cm.	
	Sample F		
0	160	2.6	2140
25	145	2.6	2320
50	195	2.6	2300
75	220	2.3	2410
100	320	1.7	2200
125 passed	300* at	0.7	2030
	Sample G		
0	135	3.0	1950
25	145	2.8	2090
50	190	2.6	2300
75	280	2.5	2330
100	250	1.3	2360
125 passed	300* at	1.6	2420
150	280	2.0	2360
175	150	2.1	1930
200	95	2.2	1880
	Sample H		
0	100	2.3	2010
25	140	2.4	2170
50	160	2.1	2170
75	190	2.1	2270
100	190	2.0	2200
125	225	1.4	2140
150	235	1.6	1740
175 passed	300* at	1.2	1380

*Force too great to make complete test.

The percentage of wet gluten decreased with increases in the quantity of hydrogen chloride used more than was effected by similar treatments with chlorine. Sample F, for the heaviest treatment, yielded

only 27.0% wet gluten, altho in the preceding treatment the amount was only 31.6%. Sample G was not so badly affected, the heaviest treatment still giving 35.8% wet gluten. For sample H, however, it was possible to recover only 19% and 16% wet gluten, respectively, on the last two treatments. The preceding treatment gave 30.5%.

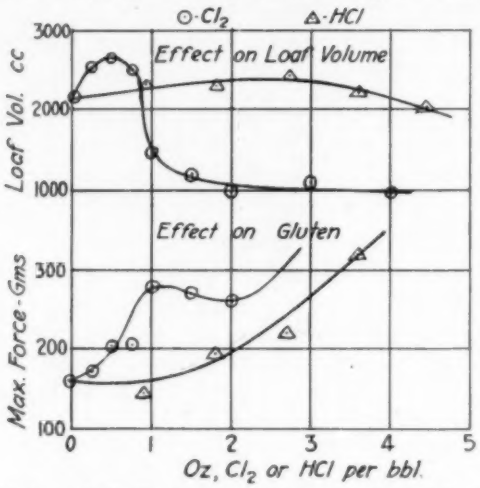

Fig. 4. Effect of Chlorine and HCl Treatment on Gluten Properties and Loaf Volume, Sample F

It will be seen that the addition of hydrogen chloride has considerable effect on the flour and that the effect on the gluten was apparently not reversed to any great extent on washing. The general trend in the change of washed gluten on the addition of hydrogen chloride was similar to that caused by chlorination. The loaf volume was also improved. However, there are some important differences in the effect of the two treatments. In Figures 4, 5, and 6, the amounts of chlorine and hydrogen chloride are shown in ounces per barrel. It can readily be seen, even allowing that all the chlorine substituting in the chlorination of the flour is hyrolyzed to HCl, that far fewer equivalents are required to produce the maximum loaf volume with chlorine than with hydrogen chloride; also that altho hydrogen chloride considerably increases the loaf volume, the maximum volumes were not so great as in chlorine treated flour. Neither did the flour show the complete collapse, as far as baking properties were concerned, with the heavy hydrogen chloride treatment.

Looking at the curves for the effect on the gluten, it will be seen that in Figures 4, 5, and 6 they show a steady upward trend, indicating an increase in the breaking force of the gluten. The curve for the clear sample H, however, finally showed a falling off in the force required to break the gluten. No dip in the gluten effect curve was found similar

to that in the chlorine curve. This demonstrates that the actions of hydrogen chloride and chlorine upon the gluten are not similar.

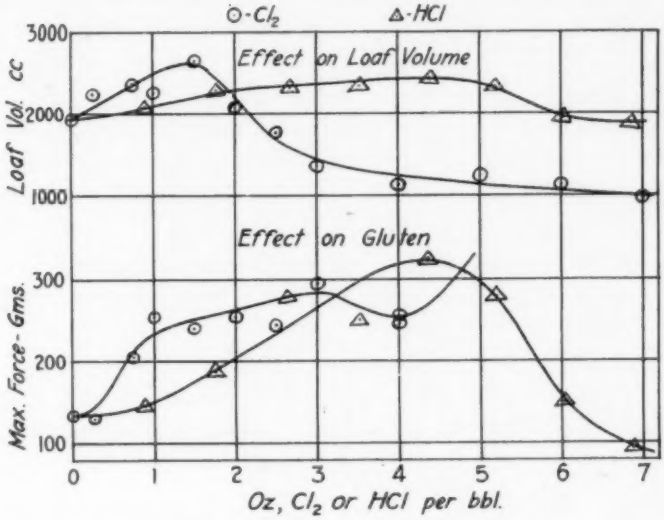

Fig. 5. Effect of Chlorine and HCl Treatment on Gluten Properties and Loaf Volume, Sample G

It is evident that the small amount of hydrogen chloride liberated by the action of chlorine on the flour is only sufficient to account for a small portion of the effect of chlorine. We feel, therefore, that the principal effect of chlorine on the flour and flour gluten must be that of oxidation.

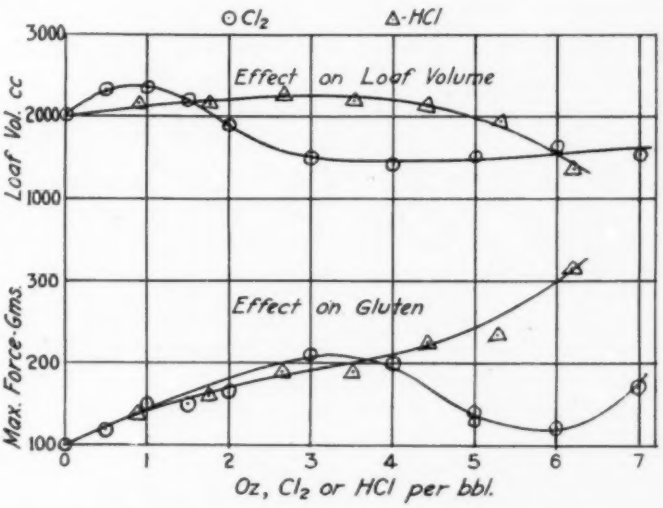

Fig. 6. Effect of Chlorine and HCl Treatment on Gluten Properties and Loaf Volume, Sample H

Discussion

It will be seen from the material here presented that the force required to extend the gluten to the breaking point is of considerable importance in flour quality. Good loaf volumes were produced only when this force was comparatively large. However, this is not the only factor to be taken into consideration in gluten quality. The chlorine treatments show that while the breaking strength of the gluten shown by the tests can be increased almost indefinitely, there comes a point where the loaf volume suddenly falls off. This may be due to the gluten becoming less sticky and finally reaching a point where it no longer acts as a good binder for the starch. It was noticed in washing heavily chlorinated samples that altho the dough had a tendency to scatter badly, the starch separated readily from the gluten. In treatment of hydrogen chloride flours the starch did not separate so readily, even from glutens that corresponded closely in physical tests with chlorine glutens. We believe this tendency of gluten to hold starch prevented the complete collapse of the dough in the hydrogen chloride bakings, which took place in the chlorine bakings as soon as the force required to break the gluten became very great.

Summary

A machine has been devised for making physical measurements upon the wet gluten of flour.

These measurements show that the breaking force of glutens differs with the variety of wheat, the glutens of hard red spring wheats normally having the highest breaking force.

The gluten of a patent flour normally has a higher breaking force than that of the clear flour.

Nitrogen trichloride and chlorine, as applied in commercial mill treatment, considerably increase the breaking force of the gluten.

Fine grinding with a cool grinder was without effect on gluten quality.

High temperature in air for an extended period of time increased the breaking force of the gluten.

Chlorine and hydrogen chloride affect the breaking force of the gluten in somewhat the same way, but a comparison of the effects on the same flour shows distinct differences.

High breaking force in the gluten is needed for good baking strength, but glutens of high breaking force may fail through other causes.

CONTRIBUTION TO THE DETERMINATION OF FLOUR ASH

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(Received for publication October 24, 1926)

In this work special attention is paid to the determination of flour ash in platinum and porcelain dishes. The burning of flour at relatively high temperature (575° C. up) was studied and the results were compared with those obtained by other investigators.

Platinum dishes were found superior to porcelain dishes for ashing flour. Every possible reaction between the container and the ash is thus eliminated, and the platinum hastens the burning of carbon. Iron is known to attack platinum, but the concentration in flour is too low to have an appreciable effect on the results.

Experiments were conducted in which the time of burning in platinum and porcelain crucibles was compared. It was found that under the conditions of the first two methods (described later) the time of burning was shorter by 20 minutes in platinum dishes than in porcelain crucibles. Under the conditions of the third method, the time of burning was also shorter in platinum dishes than in porcelain dishes, but as in this case unoxidized carbon remained in the porcelain dish, a fair comparison can hardly be made.

Several different grades of flour were ashed—short patent, A clear, B clear, low-grade, and feed. Two grams was used of flour which contained less than 1.5 per cent of ash while 1 gram or less was used of that with a higher ash content. Results are shown in Table I.

The methods of ashing employed were:

1. The temperature was raised slowly from 75° F. (24° C.) to 1300° F. (705° C.). Time required, 2 hours.

2. The temperature was raised rapidly from 300° F. (149° C.) to 1500° F. (815° C.). Time required, 1 hour 10 minutes.

3. The sample was placed in a furnace at 1700° F. (926° C.). Time required, 16 minutes.

The rate of temperature change used in the experiments is expressed in the figure.

In the first method, with flour with ash content below 0.65%, only partial fusion was observed. That which had an ash content up to 0.74% showed almost complete fusion of the ash, while the flour that had an ash content from 0.74% up, was totally fused (like glass). In the second and third methods fusion was complete in all cases.

TABLE I

ASH CONTENT OF VARIOUS GRADES OF FLOUR FOUND BY BURNING AT HIGH TEMPERATURES

Sample	Method I Ash, %	Time hr.	Time min.	Method II Ash, %	Time hr.	Time min.	Method III Ash, %	Time min.	Grams
Short patent	0.38	1	45	0.385	1	1	0.38	16	2
	0.385	1	47	0.385	1	3	0.38	16	2
A Clear	0.70	1	45	0.695	1	3	0.695	16	2
	0.70	1	46	0.70	1	2	0.695	16	2
B Clear	0.805	1	46	0.80	1	4	0.805	15	2
	0.805	1	46	0.80	1	2	0.80	16	2
Low grade flour No. I	0.955	1	48	0.96	1	4	0.96	16	2
	0.96	1	49	0.96	1	3	0.955	15	2
No. II	1.44	1	50	1.445	1	6	1.44	15	2
	1.44	1	48	1.44	1	4	1.44	16	2
Wheat	1.67	1	46	1.67	1	2	1.67	15	1
	1.68	1	46	1.67	1	3	1.68	15	1
Flour midds. (shorts)	4.24	1	54	4.25	1	8	4.25	16	1
	4.24	1	52	4.24	1	6	4.24	16	1
Bran	6.02	1	58	6.02	1	8	6.02	16	1
	6.01	1	58	6.02	1	9	6.01	16	1
Rye patent	0.58	2		0.58	1	10	0.575	16	2
	0.575	1	58	0.58	1	8	0.575	16	2

Contrary to the general belief that when fusion occurs only irregular and erroneous results can be obtained, it was found that even when complete fusion took place, the results were dependable and compared very favorably with results obtained by investigators who used the regular agricultural chemistry methods (Table II). In this method no fusion occurs, but the time required is 16 hours. The results also compared well with results obtained by Hertwig and Bailey (1924), who likewise did not allow the ash to fuse, but who used an alcohol and glycerol mixture to modify the texture of the char, or cinder. Their time was 3 hours.

TABLE II

COMPARISON OF RESULTS OBTAINED AT HIGH AND LOW TEMPERATURES

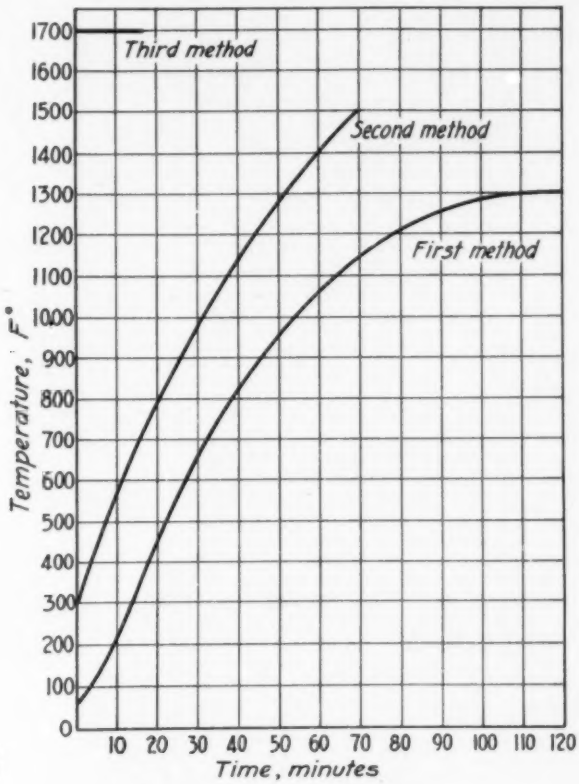
Methods	Sample 1		Sample 2		Sample 3	
1	0.40	0.40	0.65	0.655	0.92	0.915
2	.40	.405	.655	.65	.92	.92
3	.40	.40	.655	.655	.915	.915
Reg. Agr. Chem. 16 hr.	.405	.405	.65	.655	.92	.92
Hertwig-Bailey	0.405	0.405	0.655	0.65	0.92	0.915

The use of platinum and recourse to high temperature combustion shortens the process to 2 hours in the first method, to 1 hour 10 minutes in the second method, and to 16 minutes in the third method.

In the first method most of the carbon is burned before the fusion takes place and the little that remains in the fusion is easily expelled by raising the temperature.

When combustion is carried out by the second method, in which the temperature rises very rapidly, more of the carbon is enveloped by the fused alkalies and therefore higher temperature (1500° F.) is

needed to burn the carbon. If the temperature is not raised above 1300° F., a small amount of carbon may remain in the fusion, and cannot be expelled even after prolonged heating.



Time–Temperature Rise Curves

With the third method, there is immediate fusion of the alkalies at the surface which material envelops the mass and prevents any possible loss due to spattering. The fusion is almost simultaneous with ignition. In all three methods the final ash contains no carbon and the ultimate result is not vitiated by the fact that fusion had taken place. It is probable that without the use of platinum the small amount of carbon which becomes enveloped in the process of fusion cannot be burned and perhaps that is why results thus obtained are often incorrect.

Another explanation of why the investigators obtained too high and irregular ash content when they allowed fusion to take place, is that they probably used porcelain crucibles with glazed surfaces. It is possible that in the fusion some of the carbonates reacted with the silicates of the porcelain glaze, forming soft glass which is weighed with the ash, thus giving incorrect results.

In this work results obtained in platinum and porcelain dishes were practically the same, as can be seen from Table III. This is true only if we used the weight of the crucible before burning as its true weight in our calculation. But if the crucible is weighed after the burning, and calculations are made from that weight, the results are quite different in the two cases. The weight of the platinum crucible is constant before and after burning, but the porcelain crucible, if raised to higher temperature, becomes corroded, and calculations made from these weights do not agree with results obtained in the platinum dishes. (The attacking of platinum by the ash above 900° C. is discussed later.)

TABLE III

COMPARISON OF RESULTS OBTAINED IN PLATINUM AND PORCELAIN RESPECTIVELY

		Crucible 1			Crucible 2		
		First method	Second method	Third method	First method	Second method	Third method
Weight of porcelain crucible, gm.	before	16.5823	16.5807	16.5794	15.1096	15.1067	15.1052
	after	16.5807	16.5794	16.5759	15.1067	15.1052	15.1012
Difference, gm.		0.0016	0.0013	0.0035	0.0029	0.0015	0.0040
Ash, %		0.48	0.49	0.49	0.485	0.485	0.49
Weight of platinum crucible, gm.	before	19.4597	19.4597	19.4597	18.4681	18.4681	18.4681
	after	19.4597	19.4597	19.4595	18.4681	18.4681	18.4679
Difference, gm.		0	0	0.0002	0	0	0.0002
Ash, %		0.485	0.48	0.48	0.485	0.48	0.48

Determinations were also made in platinum dishes to ascertain whether the raising of the temperature above 1300° F. (1400°-1500°-1600°-1700° F.) would lead to volatilization of any part of the ash residue. It was found, however, that the results were unaltered. At 1400° F. the ash of all grades of flour fused. Further investigation was undertaken to determine whether combinations of the alcohol-glycerol reagent (Hertwig-Bailey) in platinum ware (at 1300° and 1500° F.) would hasten the process, but no changes were obtained.

Alundum (recommended by E. N. Frank) was used with platinum to accelerate the reaction (at 1300° and 1500° F.), but, likewise, no hastening of the reaction was observed.

A detailed study of the calcium acetate method was undertaken because preliminary experiments pointed to a definite reduction of time of burning. As previously stated, three methods of procedure developed: By the first method the time of burning was shortened from 2 hours to 1 hour 15 minutes; by the second method from 1 hour 10 minutes to 40 minutes; by the third method from 16 minutes to 12 minutes. It is probable that the hastening of the reaction by the calcium acetate is due to its physical rather than its chemical action. Its efficiency is undoubtedly due to its fluffiness and porosity, with a consequent increase of the surface of combustion and the surface exposed to the air.

The increase of the surface-contact of the flour and platinum obviously plays a part, too, as it was shown experimentally that the rate of burning is also a function of the surface of the flour-platinum contact. Flour burned alone congeals, forming a globule in the center of the crucible, which with its small surface burns very slowly at low temperature, and probably tends to form graphite at high temperatures. The addition of the acetate prevents the caking of the flour. Previous investigators claim that fusion does not take place under these conditions. The fact is, however, that fusion of the alkalies in ash takes place just the same—why shouldn't it? but the fused material is absorbed by the highly porous calcium oxide which does not fuse, and so the fusion is not evident.

As is well known, the calcium carbonate begins to decompose at low red heat, that is, below 500° C. Under these conditions the calcium oxide residue is obtained in an amorphous form of decided porosity. Calcium acetate, on the other hand, begins to decompose into calcium carbonate at 120° C., which, in turn, at higher temperature, is decomposed into calcium oxide and carbon dioxide. However, the calcium oxide obtained is not the fluffy, porous form which is obtained when the flour-calcium-acetate mixture is burned. The residue in this case seems to be of a heavy congealed type. It was further shown that calcium carbonate does not decompose quantitatively when heated alone or with flour below 900° C. Repeated experiments were carried out in heating of pure calcium carbonate and the mixture of the same carbonate with flour, but in no case was it possible to obtain concordant results (when heating was carried out below 900° C.). It was also impossible to obtain uniform results when two samples of pure calcium carbonate were heated simultaneously or under the same conditions (under 900° C.). Above 900° C. the carbonate decomposes quantitatively regardless of whether or not flour is used. However, as the presence of the acetate reduces the time of combustion only from 16 to 12 minutes, the small reduction in time does not warrant its use. Furthermore, it must be borne in mind that the use of the acetate entails an additional error in weighing. When residues as small as those involved in ash determinations are concerned, the importance of accurate weighing can be easily understood. An error of ± 0.0001 gm. can be expected in weighing 2 gms. of flour. An error of ± 0.0002 gm. is introduced when the solution of acetate is added. The combined probable error is therefore ± 0.0003 gm. As the total weight of the ash is usually from 0.0070 to 0.0140 gm. it is obvious that the error introduced by the addition of the acetate is by no means negligible.

The hygroscopic property of calcium oxide makes it difficult to weigh accurately.

Furthermore, it is possible that calcium oxide when heated at high temperature may combine with some inorganic acids (P_2O_5,SO_3) which, in the absence of the former, would be distilled off.

In view of all these sources of error introduced by the addition of calcium acetate or calcium carbonate, it can hardly be recommended for use where accurate and reliable results are desired.

The results of some of the experiments are given in Table IV. In the first two lines are given the results obtained by direct combustion. In the next two lines are given the results obtained by the calcium acetate method. In the succeeding lines appear the results obtained on reheating the ash residue for various lengths of time.

The acetate solution used in the experiments, the results of which are given in Table IV, was prepared as follows: 1 gm. calcium acetate was dissolved in 200 cc. of pure glacial acetic acid. The calcium acetate content was determined by titration with hydrochloric acid (the calcium was precipitated as calcium oxalate CaC_2O_4, which after changing to CaO by heating was titrated with hydrochloric acid) and was found to be 0.0055gm. $Ca(CH_3COO)_2$ per cc. Three cc. of this solution was used per 2 gm. of flour, or else 0.1 gm. $CaCO_3$ was used instead.

TABLE IV

COMPARISON OF RESULTS OBTAINED BY DIRECT METHOD AND ACETATE METHOD

	First method		Second method		Third method	
	Sample		Sample		Sample	
	1	2	1	2	1	2
Direct method	0.42	0.74	0.415	0.74	0.415	0.74
	.42	.74	.42	.74	.415	.745
Acetate method	.47	.765	.40	.79	.42	.745
	.45	.77	.435	.77	.415	.745
Reheated ¼ hr.	.46	.78	.43	.755	.42	.74
	.47	.765	.44	.785	.415	.74
Reheated ½ hr.	.445	.76	.445	.76	.425	.745
	0.455	0.775	0.45	0.775	0.425	0.745

No marked loss of weight of the platinum crucible was observed after 6 months constant use; as a matter of fact the loss of only 0.0003 gm. platinum per month was entailed when the first method was used. This was probably due to rubbing the crucible with sand in cleaning; the crucible always having been first washed with normal HCl and then rubbed with fine sand.

In the second method, also, practically no platinum was lost. The third method was accompanied with a considerable loss of platinum; 0.0002-0.0003 gm. for each combustion. Hence this method should be used only where the time factor is of great importance and where the loss of platinum is immaterial.

The flour contains traces of iron (according to Teller the patent flour contains 0.00145% of ferric oxide) which, of course, remains in the ash. This forms an alloy with the platinum of the crucible. On heating, the iron in the alloy is oxidized. During washing with hydrochloric acid, the oxide on the inside of the crucible is removed, while that on the outside is not. This accounts for the characteristic grayish appearance of the platinum crucibles after having been used for some time in the ashing of flour. To clean a crucible thoroly, it is first heated in an electric furnace in contact with oxygen. This insures complete oxidation of the iron. The crucible is then placed into molten potassium bisulphate $KHSO_4$, which dissolves out the iron oxide.

Conclusions

1. Platinum was found to be best suited for the ashing of flour.
2. Fusion does not lead to irregular and erroneous results if a platinum dish is used.
3. Such substances as the alcohol-glycerol reagent and alundum do not shorten time of burning at high temperatures, if platinum ware is used.
4. Three modifications of the calcium acetate method were employed. In all three cases the time was shortened. The results were found to be unreliable, unless the temperature of the muffle furnace was above 900° C. Probable causes of these discrepancies are given.
5. Best method for ashing flour proved to be the direct burning at high temperature in platinum without the addition of other substances.

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USE OF CHROMATE-SOLUTIONS AS COMPARISON-STANDARDS FOR THE DETERMINATION OF "GASOLINE COLOR VALUES"

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(Received for publication May 25, 1927)

In another publication[1] the author has emphasized a fact, which has not, so far as it can be seen, hitherto been regarded, namely, *that solutions of chromates and bichromates must be considered as hydrogen-ion indicators.*

The description of two very simple experiments, which prove this fact, shall be cited from the publication mentioned above.

Experiment 1

Seven of Sørensen's well known "phosphate buffer mixtures"[2] were prepared, namely "0.1 sec.", "0.25 sec.", "0.5 sec.", "1 sec.", "5 sec.", "8 sec.", and "9.5 sec." In seven test-tubes was pipetted 10 cc. of each of these phosphate mixtures and to each test tube was then added 1 cc. of a 2 per cent aqueous solution of $K_2Cr_2O_7$. In these seven tubes then appeared a nice color change from red-yellow (in the most acid solutions) to lemon color (in the least acid solutions). In the last mentioned solutions it lasted some seconds before the lemon color appeared. After the addition of the bichromate solution, H-ion concentration as pH in the seven solutions was measured (20° C., electrometric measurement). The results appear from the table beneath.

The steepest color change seemed to appear between pH = 6 and pH = 7.

Experiment 2

Of the same seven phosphate mixtures mentioned above, 50 cc. was pipetted in each of seven test tubes and to each tube was added 5 cc. of a 0.05 per cent aqueous solution of K_2CrO_4. In these seven solutions also appeared a color change from red-yellow to lemon color, but all the colors were less intensive than in Experiment 1. After the addition of the chromate solution, H-ion concentration as pH in the

1 Biochemische Zeitschrift, 186: 485 (1927).

2 See Clark: Determination of hydrogen-ions, 2d Ed., p. 114. Williams and Wilkins Co., Baltimore, (1923).

seven solutions was measured (20° C., electrometric measurement). The results appear from the table beneath.

When these solutions are compared two by two in a Dubosq colorimeter it becomes evident how much pH influences the color tone in such a weak chromate solution.

H-ion Concentration
of Sørensen Phosphate Buffer Mixtures after Addition
of Bichromate and Chromate Solutions

Na_2HPO_4, M/15, cc. ("sec.")	0.10	0.25	0.50	1.00	5.00	8.00	9.50
KH_2PO_4, M/15, cc. ("prim.")	9.90	9.75	9.50	9.00	5.00	2.00	0.50
10 cc. of the phosphate mixture + 1 cc. of 2% $K_2Cr_2O_7$, pH =	4.85	5.15	5.45	5.75	6.60	7.05	7.30
50 cc. of the phosphate mixture + 5 cc. of 0.05% K_2CrO_4, pH =	5.15	5.40	5.65	5.95	6.85	7.45	8.00

In Experiment 2 the concentration of the chromate is, approximately, the same as in that chromate solution which Winton[3] employs in his excellent gasoline color value method.

In view of the extent to which the color tone of such a chromate solution depends on pH, and how indefinite is the pH of distilled water (especially because of the influence of the alkali of the glass) it will be understood that the color of such a weak solution of chromate is *undefined*.

The author, therefore, has proposed that in preparing such comparison standards, potassium chromate shall not be dissolved in water, but shall be dissolved in a buffer solution.

We have, till now, been very content in using Sørensen's "0.5 secondary + 9.5 primary phosphate" as solvent for the potassium chromate. In this solution the chromate takes a color which seems to us to be very similar to that of the gasoline extracts of wheat flour.

Winton mentions that the gasoline extracts from some sorts of wheat flour can possess a color which differs from the usual color of such extracts.

In connection with these observations we shall draw attention to the fact that it is possible, in varying the buffer mixtures in which the chromate is dissolved, to prepare solutions possessing many different *defined* red-yellow and yellow color tones.

Perhaps it will be possible in this way to prepare solutions which can be used as comparison standards in cases where the color of the gasoline extracts differs from the usual color.

3 Winton, A. L. Color of flour and a method for the determination of the "gasoline color value." Proc. 27th Ann. Conv. A. O. A. C., U. S. Dept. Agr., Bur. Chem. Bull. 137:144-148, (1911).

THE WORK OF THE BAKERY ENGINEER IN RELATION TO THAT OF THE FLOUR MILL CHEMIST

By E. B. PRICE
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(Read at the convention May 30, 1927)

In considering the subject "The Work of the Bakery Engineer in Relation to That of the Flour Mill Chemist," I want to explain the reason for the foundation of the American Society of Bakery Engineers; its needs, its aims, and its successes. About four years ago a group of ninety-seven men, interested in bakery production, met together in Chicago to talk over their common problems and in so doing, through frank and open discussion, to attempt to better the lot of each individual. In the past there had been very little communication or connection between the production men, the old-time policy of staying in their own sphere and guarding their work as secrets was indulged in. These ninety-seven men realized that there are no secrets in the baking industry and that by meeting together in common discussion they would benefit themselves and benefit their industry. Its aims are best set forth in the original constitution, and are as follows:

(1) By bringing together for conference and discussion the men in the baking industry responsible for production.
(2) By educating the industry to a better appreciation of the importance of trained bakery production superintendents.
(3) By setting standards of education and training which will bring the bakery production superintendents the recognition they are entitled to as engineers.
(4) By promoting an intelligent understanding on the part of the public of the fact that the production of bakery goods is in the hands of specialized and highly trained men.

The principles upon which the society is founded are fundamentally sound and its success as an organization is best pointed out by the unheard-of growth in bakery history, from a beginning of ninety-seven men to a total membership at the present time of approximately seven hundred and fifty. This in the space of four short years. It has accomplished the weaving together of one of the strongest forces in the baking industry. It has promoted closer understanding of the men and their work. It has created a keener appreciation of the necessity of producing the highest quality loaf possible in the most economical and scientific as well as practical manner. It is attempting to further the knowledge of materials and processes so that the value that lies in quality materials may be

shown in the finished product. It has established correlation with other societies allied with the baking industry and closely affiliated with bakery production work; this for a better understanding of mutual problems. It has attempted to standardize equipment so that uniformity may be had without sacrificing efficiency. It has attempted to eliminate the erroneous use of terms which would cast a reflection on the baking industry.

But in regard to the subject assigned, may I state that the work of the bakery engineer is very closely allied with that of the mill chemist, for it is the bakery engineer's job efficiently and scientifically to manufacture into wholesome food the product which you mill chemists have efficiently and scientifically manufactured. In other words, you mill chemists and we bakery engineers are but a link in the cycle and the better we understand our own problems and the problems of each other, the better we can justify our individual existence and the existence of our societies. Our problems are many and varied, but many of them are mutual, and I respectfully ask for a close correlation of activities of your society and ours so that in the end we may both wholly fulfil our obligation of giving the highest quality food to our ultimate customers, the general public.

In speaking of our problems, let me state just a few in which you are interested and, in a way, responsible. The most important material which the baker has is flour, especially at this time, owing to the fact that we are all confronted with the same problem of holes in bread. The reasons given for this are varied and of great number. Blackhull wheat, bleaching, storage, method of threshing, and method of milling are among those most prominently mentioned. It is my frank opinion that no one has been able to tell us definitely the reason for holes. We know that holes in bread exist regardless of the section of the country from which the flour comes. We know, too, that in some sections from which flour comes the holes are more prevalent than in others. Experiments have shown us that blackhull wheat, while not entirely responsible, perhaps has a larger percentage of complaints than any other. We also know that the flour is not entirely responsible for this condition, nor is it our belief that the large number of complaints which have been laid to your door are justified. At the same time we bakery engineers have that as our foremost problem and I was much interested in receiving an educational bulletin stating that the holes in bread are due entirely to the baker not having the proper fermentation factor for the flour he is using. It was stated that each flour has a definite fermentation

factor and that when this factor is discovered all trouble will cease. In answer to this, the author of this article may be right, but if he is right then 95%, at least, of all the bakery production men in the country are wrong; and I, as a practical baker, confronted by this daily problem, am far from satisfied with such an explanation. In running dozens of test doughs, even going to extremes in variation of temperatures, time, formulas, and processes, we have found how to decrease the holes but not to eliminate them. This is our largest problem, and it is hoped that some definite solution can be given to the bakery engineers so that quality will not continue to suffer.

In speaking of quality, I will also give you one of our problems in which we are vitally interested. You have no doubt heard a lot recently regarding the decreased consumption of wheat and the decreased quality of bread. Regarding the former, I doubt very much the statement that there is an alarming decreased consumption of wheat for the simple fact that the increased yield is approximately the same percentage as the decreased consumption; but I do know that the average bread quality has been decreased and this has been due to a large extent to the baker foolishly trying to meet price competition; and in meeting price competition and to eliminate loss of profits, he has been cutting quality. We have attempted to combat this by continually preaching the well known fact that bread can only be as good as the quality of ingredients that enter into its manufacture. This must be taken with the proper consideration of efficient operation and a thoro understanding of the proper manipulation of these quality ingredients. The trend of the average baker has been toward longer extraction of flours. In justification of this he is loading his formula with other high-class ingredients, making a very rich loaf which in reality is competing with the cake baker. In a recent nation-wide canvass, a number of bakers' formulas were found to be entirely out of balance. Two particular cases were using an enormous excess of sugar, milk, and lard, and a 95% patent flour. It was shown these bakers that by using the proper percentage of quality ingredients and taking the saving on these ingredients, he could purchase a short patent flour, which together with the proper percentage of quality ingredients would greatly increase the quality of his bread and better satisfy his consumer demand by producing a loaf with the appetite appeal of the now almost forgotten "wheaty flavor." In a number of shops it has been further shown that by increasing efficiency of operation and cutting down controllable and invisible losses, the saving made would far offset the saving he was making in the suicidal method of cutting quality.

The fallacy of striving as we have in the past for extremely high absorptions and extremely high yield has also been shown. Also, there has been a reaction on the part of the bakery engineers against over-bleaching flour. This is a very ticklish subject and one on which progress will have to be made very slowly, but it is our belief that steps should be taken some time in the future to accomplish this end, paying particular attention not to have undue unfavorable criticism on the part of the public.

At a meeting in the East last week there was criticism against the flour mills from the standpoint that it was almost impossible for the baker to tell the flour salesman the kind of flour he desired in his plant. This criticism was answered by stating that I believe the trouble lay with the baker rather than with the flour salesman because in quite a number of instances the flour buyer, owing to the varied nomenclature used in the description of flour, had him so confused that it was almost impossible for him, in baker's language, to describe just what he wanted. I believe this subject could be well handled by a common understanding of types, grades, and results which can be obtained from the various flours on the market. In this connection may I state, with all due respect for the work done by you chemists, that to the average baker the baking tests and the laboratory tests which are sent out to the flour buyer mean very little, if anything, in the purchasing of flour. Until some method of testing, both from chemical analysis and baking tests, is arrived at, which has as its foundation the actual shop test, I believe that very little progress will be made in the sale of flour by the present method. Please do not misunderstand me in criticising your tests from the standpoint of securing uniformity and control of flour manufacture. I am speaking from the standpoint of the baker who would like to have his shop methods translated into reports, by you mill chemists, so that he can purchase flour that will most suit his shop needs, and be assured of its delivery.

I realize that the subject assigned is very large, but I also realize that through a closer study of our common problems we, as bakers, can further appreciate the exceptional work of the American Association of Cereal Chemists and that you men can also know the problems that your product is forced to undergo. If it is in line, I believe it would be a great advancement to have committees from both our societies attempt to solve many of the unsolved problems, so that we may together further the American baking industry and in so doing further and make easier our individual efforts.

COLLABORATION WITH THE ASSOCIATION OF OFFICIAL AGRICULTURAL CHEMISTS

By RAYMOND HERTWIG

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(Read at the convention May 30, 1927)

Introduction

An efficient co-operation between organizations is possible only when there is a mutual thoro understanding of their respective purposes, their individual fields of activity, and their procedures of operation. More or less lack of such understanding has been an important factor in the failure of the American Association of Cereal Chemists and the Association of Official Agricultural Chemists (usually referred to as A. A. C. C. and A. O. A.C.) to build up between them a strong and effective co-operation for their mutual advantage. The few contacts between their respective leaders and active members also have been a cause for the present rather sporadic, unplanned, and unsystematic co-operation. Mainly because of these reasons the two organizations have worked quite independently and more or less heedless of each other's efforts and needs in their respective studies of analytical methods. This indifferent relation is to be regretted. The growing prominence and activities of the cereal analytical studies of both organizations have developed an increasing need for the benefits to be derived from a well planned, constructive, and efficient co-operation.

It is not the intent of this discussion to make charges or show errors on the part of either association. It is intended only to relate briefly the nature of the A. O. A. C. as an organization, its functioning, the advantages to be gained by our co-operation as an association in its studies of methods of analysis of cereal foods and feeding stuffs, and to propose a plan for consideration whereby efficient co-operation may be attained.

Nature of the Association of Official Agricultural Chemists

The A. O. A. C. was founded in 1884. The membership is institutional and comprises the state departments of agriculture, the state agricultural colleges and experiment stations, the federal department of agriculture, and the federal, state, and city offices charged with the enforcement of the food, feed, drug, fertilizer, insecticide, and fungicide control laws. Because of the nature of

the membership it is a kind of quasi-governmental organization altho in reality it is independent of all government control.

The purpose of the association is to bring together in ordered form accurate and equitable methods for the analysis of agricultural products and materials related to agriculture and to afford opportunity for discussion of related matters. Under its direction new methods are developed, studied and, after proper consideration, adopted. Old methods in like manner are constantly being modified. The studies of methods are published in the association's journal. Adopted methods are given in the Book of Methods, a revised edition of which is to appear each five years. Methods for the analysis of about thirty comprehensive subject-groups of materials are now included in the collection and several others are to be added.

It is to be clearly understood that the activities of the A. O. A. C. are confined to the study of methods of analysis themselves and do not embrace problems and investigations wherein these methods are applied. Our association, on the contrary, is primarily interested in the results of application of analytical methods and in investigations in which the methods are incidental. Therefore the activities of the A. O. A. C. coincide only with a limited portion of our association's activities—the development and study of analytical methods. Co-operation with the A. O. A. C. is consequently limited to this common field where interests overlap.

The system whereby the A. O. A. C. studies, considers, and adopts its methods of analysis is designed to assure their accuracy, merit, and equity for application by all who may find use for them. A general referee is made responsible for the methods of each subject-group of products and for the studies undertaken for their expansion and development. He obtains the co-operation of associate referees designated to study individual methods. The associates are selected because of some particular qualification for the specific assignment and usually have some direct interest in connection with their studies. All methods developed or studied are submitted to a number of analysts for independent trial and criticism. The associate referees report their own studies, the collaborative results, and their recommendations direct to the association. The general referee reviews the associates' reports, considers their recommendations, prepares a report summarizing and correlating all the various studies, and also makes his own

independent recommendations covering the entire subject-group. All the reports are submitted to a special committee on recommendations of referees for re-consideration and approval. This committee on recommendations is composed of persons having considerable experience in the association's policies and functioning and their recommendations are read before the convention sometime subsequent to the presentation of the respective referees' reports. The association votes upon the committee's recommendations. Members present have opportunity to contest recommendations on the floor of the convention. This rather elaborate scheme for the consideration of the referees' studies and recommendations tends toward the adoption of only those recommendations worthy of the association's recognition and which react to its welfare.

A method is adopted as "tentative" only after it has been studied collaboratively, is favorably recommended by both its respective referee and the special committee on methods, and is finally accepted by vote of the association. A tentative method becomes "official" in accordance with the foregoing procedure upon its second favorable presentation and acceptance at successive annual conventions.

The methods of the A. O. A. C. are held as official for the enforcement of the various state and federal laws for the control of foods, drugs, feeds, fertilizers, insecticides, fungicides, etc. This recognition before the state, city, and federal courts possesses the methods with a dignity, authority, and general acceptance that is enjoyed by no other set of analytical methods. Their general use by governmental laboratories gives the A. O. A. C. methods a unique position of advantage that tends to make for their universal acceptance.

The A. O. A. C. is a kind of depository for agricultural analytical methods. It functions to give stability and validity to agricultural analysis. The methods pass as a kind of analytical legal tender and bear the stamp of genuineness. Their results are accepted at face value in all circles. In this accomplishment, the A. O. A. C. has done a momentous service that deserves highest appreciation. That that organization will extend its services and activities in the future is to be expected. Indeed, such extension is believed imminent.

The quasi-governmental nature of the A. O. A. C. and the purposes set for it limit the scope of its activities. It cannot be

looked to for aggressive and original studies and investigations for opening up new fields of endeavor. Such pathfinder work befits more the purpose of such organizations as our own. The A. O. A. C. organizes, stabilizes and standardizes fields of analytical agricultural chemistry that have already been opened up and developed. The methods of the A. O. A. C. are adopted after need exists for standard analysis of agricultural products in economic transactions. Our association, on the other hand, is impelled by impulses for progress and by the interests we serve to reach out into the unknown and extend agricultural chemical knowledge and to solve new problems that present themselves. The analytical methods developed and involved in these investigations are of secondary importance.

Any co-operation with the A. O. A. C. must be guided by knowledge of the intrinsic nature of that organization as well as of our own association, and the individual purposes of each must be kept well in mind and respected. The A. O. A. C. jealously guards its unique position and character of being an unprejudiced organization, free from selfish ambition and motive, and is independent of all obligations except the collection of equitable and accurate methods of analysis. The A. O. A. C. and the A. A. C. C. hold important positions in the progress of applied agricultural science and their respective places are side by side. They are not contending organizations, they are comrades in a common cause.

Benefits of Co-operation

With the preceding general understanding it is now pertinent to consider concrete benefits derivable from official co-operation with the A. O. A. C.

First, the question arises, does the A. O. A. C. favor the co-operation of other associations in its activities? Published statements by its officers indicate that it whole-heartedly welcomes such outside collaboration and active interest in its work. Official co-operation by that association with certain organizations in the past for the accomplishment of specific purposes bears evidence to that effect. It is the writer's personal experience and opinion that the A. O. A. C. favors any proper co-operation by outside agencies that acts to its welfare and which is in harmony with its policies for disinterested equity and accuracy of its methods.

In that it is to the interest of our association and of the A. O. A. C. to have only the most accurate and practical analytical methods for cereals and feeding stuffs, it is apparent that without

proper co-operation there ever will be considerable duplication of effort in their independent activities. This is wasteful of valuable energy and time and retards the progress both parties are striving to make. Planned and systematic co-operation can greatly reduce such unnecessary duplication.

It is advantageous, for many self-evident reasons, that analyses of cereals and feeding stuffs by governmental, industrial, and other laboratories be made by the self-same methods wherever possible and that results be reported in a standardized manner. Co-operation between all interested associations and agencies is the most likely way of attaining this much desired end. The A. O. A. C. holds the position of leadership and advantage in this respect, owing to the recognition of its methods before the courts, its quasi-governmental nature, and the unbiased character of that association. It, more than any other agency, exercises the strongest influence for standardization of agricultural analytical methods. Co-operation with it will obtain far greater and quicker results than individual and independent efforts by other associations.

Co-operation with the A. O. A. C. should bring the methods studies of the two organizations under the concerted scrutiny and criticism of a larger number of chemists with greater diversified interests and experience. This extension of the critical study of the methods should enhance the value of the resultant adopted methods.

The incorporation of all worthy cereal and feeding stuffs methods with the methods for other agricultural products in the A. O. A. C. Book of Methods is a great convenience and carries many advantages. This book has a wider distribution than our association can expect for any similar publication. It is to be found in every laboratory that professes to analyze agricultural products. It is a common laboratory text in our educational institutions. Methods that gain recognition as official in this Book of Methods are extensively used and have authoritative standing. Any method that has real merit and that is capable of meeting the requirements of the A. O. A. C. can find place among its methods through proper co-operation with that association. Indeed, such co-operation can greatly aid the studies of analytical methods of our association and in addition finally result in the incorporation of at least most of the methods in the A. O. A. C. Book of Methods without loss of any independence of our investigations.

Co-operation with the A. O. A. C. will extend and increase the contacts between governmental, research, and industrial cereal chemists, bring about greater exchange of ideas and experience between them, and lead to a better understanding of their respective problems and ambitions. The broadening of the views of all these parties will be reflected in more efficient and satisfactory methods for cereals and feeding stuffs.

Direct interest in the A. O. A. C. methods studies should stimulate the work of both associations. We can contribute much to their progress and they much to our progress. Working in harmony with the A. O. A. C. for a common goal should react to our benefit in numerous ways. Such co-operation should promote still more active interest in our own analytical studies and keep more definitely before us the purposes we are striving to accomplish. It should bring into rightful prominence this painstaking and vitally essential activity of our association.

Proposed Plan for Co-operation

There now remains to be discussed a possible practical procedure for collaboration with the A. O. A. C. In this connection it is emphasized that our association would under no condition consider the surrender of the independence of its own methods studies, nor permit of even partial loss of control of these studies. Such is not intimated and would be utterly unacceptable to either association. The relation of the two associations is therefore limited to a practical co-operation such as can exist between independent sovereign organizations that recognize and respect each other's existence and purposes.

It is believed that the accomplishment of the ends mentioned may be attained by the appointment of a committee authorized to make contact with the proper officers of the A. O. A. C., to bring before them officially matters that our association would respectfully submit for their attention, and to consider with them all ways and means whereby the associations can mutually assist each other. This committee may to advantage include the chairmen of our executive, allied associations, and methods committees and any others who by experience may be considered particularly qualified to promote sympathetic and helpful relations with the A. O. A. C.

Possible activities of the committee may be briefly itemized.

(a) Submittal to the proper A. O. A. C. officers of matters, comments, and suggestions pertaining to cereal analytical methods which according to the consensus of opinion in

our association deserve their attention and would react to the profit of both organizations.

(b) Representation of our association at the A. O. A. C. conventions and the presentation of papers on subjects of interest to both organizations.

(c) Contacts with A. O. A. C. officers to strengthen sympathy and a spirit of co-operation.

(d) Consultation with A. O. A. C. officers to avoid unnecessary duplication of effort and studies by the two associations.

(e) A report of the committee's activities at our annual conventions with recommendations for our association's consideration and action.

(f) Rendition of assistance at the request of A. O. A. C. officers to make the chapters on cereal foods and feeding stuffs in the A. O. A. C. Book of Methods complete records of the highest qualified and most modern analytical methods.

(g) Solicitation for initiation by the A. O. A. C. of any studies which that association can more effectively prosecute than can our association.

(h) The formulation with the A. O. A. C. officers of a co-operative and co-ordinated program for promotion of studies of cereal and feeding stuffs methods.

(i) To capitalize to our association's profit all potential benefits previously mentioned and realizable by co-operation with the A. O. A. C. Finally, this committee can serve as a bond of union between the A. A. C. C. and the A. O. A. C. and bring them to a better mutual understanding, to a greater mutual service, to a greater realization of their obligations to each other, and to a closer fellowship in a common cause—the advancement and development of agricultural analytical methods.

A METHOD FOR PRECISE MEASUREMENT OF THE VOLUME OF TEST BISCUITS

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(Received for publication June 13, 1927)

In 1914 the writer had occasion to make accurate measurement of volume of several series of test biscuits in a comparison of the leavening power of two baking powders. A search of the literature available at that date did not disclose a sufficiently refined or accurate procedure for the measurement of minute differences in the specific volume of baked products.

To meet the requirements of the work, a method was developed which was based upon the displacement of sized (−40, +60 mesh) sea sand, which has proved to be much more sensitive and accurate and no more difficult of execution, than the previously recommended procedures employing rape seed[1] or mustard seed.

A list of requisites, together with a statement of the essential details of manipulation and data showing the accuracy of the method, follows:

Requisites

1. A balance of 1000 g. capacity; sensitive to 0.01 g.
2. About 500 cc. of washed, dried and sized (through 40, but retained on 60 mesh screen) sea sand.
3. A 300-cc. measuring flask with long narrow neck from which the flange has been cut and the end made straight by grinding. Or, there may be attached to the flask neck, by means of flexible rubber tubing, a short, fire-polished glass nozzle, constricted slightly at one end by a shoulder to impede the discharge of sand (Fig. 1).
4. No. 40 thread and small sharp scissors.
5. The weight, capacity in cc., and in grams of sized sea sand, of a flat bottomed, straight sided, water glass (about 3¾x2⅝ inches) when filled under special and uniform conditions. The rim of the glass must be true, smooth, and perfectly free from imperfections detectable by slowly drawing the edge of a knife across the rim.
6. A case knife with smooth, polished blade, about 12x1⅛ inches. The knife edge must be straight, reasonably sharp, and perfectly smooth.
7. A metal dough cutter about 2⅝ inches long and 1⅜ inches wide above the center, shaped oval at one end and tapered to a blunt point at the opposite end (Fig. 2).

1 Jackson, H. L. Am. Food J. 8:437 (1913).

The biscuit obtained from the use of this cutter on dough rolled to half-inch thickness is of suitable size for measurement in a water glass, as described in paragraph 5.

Fig. 1. Glass Nozzle

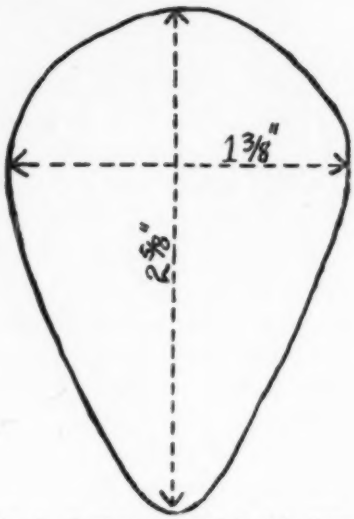

Fig. 2. Section of Metal Dough Cutter

Manipulation

1. Determination of Capacity of Water Glass in Grams of Sized Sea Sand

Fill flask completely with sand and invert on the bottom of the glass in such a manner that no sand escapes when the glass is placed in vertical position on the table.

Cautiously raise the flask *at uniform speed* allowing the sand to *flow gently* and *smoothly at a uniform rate* until the glass is filled to overflowing *over the entire rim.*

(In this operation the sand must not fall, must not roll down longer slopes on one side than on the other, must not receive pressure from the flask neck, or nozzle, and must be *protected from jar.*[2] The complete filling must be accomplished with one charge of sand from the flask.)

Cut off the cone of sand level with the rim of the glass by passing the sharp edge of the 12-inch case knife (held level, both hands, blade vertical, edge down) down through the center of the cone of sand to the point of *gentle contact* with the rim of the glass. When the knife is in accurate contact with the rim on both sides, remove half of the cone by drawing the knife forward; the other half by carefully replacing the knife in position on the rim and pushing.

[2]The sand flask may be raised by a mechanical device of the nature of a windlass. The technic of the writer has been to grasp the neck of the flask in the fingers of the right hand, support the right wrist with the left hand and raise steadily at a uniform rate, which permits the sand to flow gently and smoothly.

It is essential for concordant results that the sand mass be not jarred during the operation of "striking off" the cone.

Experimental Data

Weight of glass	92.02 g.
Weight of glass + water at 15° C.	379.70 g.
Capacity of glass	287.68 cc.

Filling	Glass + Sand	Sand	Variation from mean
	grams	grams	grams
1	532.50	440.48	0.10
2	532.30	440.28	0.10
3	532.55	440.53	0.15
4	532.45	440.43	0.05
5	532.30	440.28	0.10
6	532.30	440.28	0.10

Average of six measurements 532.40 g.[3]

One gram of sand = 0.65 cc.

Maximum difference from the mean in filling the glass of 287.68 cc. capacity = 0.15 g. = 0.097 cc. = 0.03%

Mean error of a single measurement, calculated by the method of least squares:*

$$\pm 0.6745 \sqrt{\frac{.0650}{5}} = 0.049 \text{ cc.} = 0.017\%$$

2. Determination of the Grams of Sand Displaced by a Test Biscuit

(The biscuits, baked in open pans, or on aluminum plates, are weighed individually as soon as they attain room temperature. At the moment measurements are commenced on one biscuit the remaining biscuits of the lot should be placed under a bell jar to prevent further loss of moisture.)

Suspend the weighed biscuit, by means of a loop of No. 40 thread,[4] pointed end down, and within about ¼ inch of the bottom of the empty glass. Introduce into the biscuit, at triangular points, three short headless pins and adjust the protruding shaft to ¼-½ as required, to prevent the biscuit from touching the side of the glass during the filling in of the sand. Tilt the glass (suspended biscuit resting on two of the pins), pass the neck, or extension nozzle, of the filled sand flask to the

[3]The weight 532.45 g., the average of another series of measurements on a larger sample of the same sand, has been used in the work presented in 2.

*$\pm 0.6745 \sqrt{\frac{\Sigma \delta^2}{n - 1}}$

$\Sigma \delta^2$ is the sum of the squares of the deviations from the mean; n is the number of determinations; 0.6745 is the probable error constant.

[4]The thread may be attached to an adjustable clamp on the rod of a retort stand.

bottom of the glass without discharging any sand and bring the glass to vertical position on the table. Cautiously raise the flask and allow the sand to flow *under and around* the biscuit, as described, changing the position of the point of sand discharge around the biscuit as required to avoid long slopes, until the glass is filled to overflowing. Cut the thread close to the sand with scissors *(do not touch the sand nor pull the thread)*, "strike off" the cone of sand with the knife, as described, and weigh.

Experimental Data

Glass + sand = 532.45 g.
One gram of sand = 0.65 cc.

Measurement	Biscuit A Weight 25.985 g.				Biscuit B 25.680 g.			
	Glass biscuit sand	Sand displaced		Diff. from mean	Glass biscuit sand	Sand displaced		Diff. from mean
	grams	grams	cc.		grams	grams	cc.	
1	471.70	86.73	56.65	0.06	472.10	86.03	56.19	0.05
2	471.63	86.80	56.70	0.01	472.00	86.13	56.26	0.02
3	471.70	86.73	56.65	0.06	472.10	86.03	56.19	0.05
4	471.57	86.86	56.74	0.03	471.95	86.18	56.29	0.05
5	471.60	86.83	56.72	0.01	472.05	86.08	56.23	0.01
6	471.52	86.91	56.77	0.06	472.10	86.03	56.19	0.05
7	.....	.....	.....	.....	472.00	86.13	56.26	0.02
8	.....	.....	.....	.....	471.95	86.18	56.29	0.05
Average			56.706		.....	.....	56.238	

Mean error of a single measurement calculated by the method of least squares.

$\pm 0.674 \sqrt{\frac{.0119}{5}} = 0.032$ cc. $= 0.056\%$ $\pm 0.674 \sqrt{\frac{.0134}{7}} = 0.029$ cc. $= 0.051\%$

Conclusion

The volume of properly shaped solids may be measured by displacement of sized sea sand when delivered under conditions that permit uniform flow and avoid unequal packing effects.

The probable error of this method applied to the measurement of volume of small baked products, as 60 cc. biscuits, is shown to be less than 0.1%.

The possible accuracy of the procedure, conducted with a standardized technic, compares with that attainable with most standard methods of chemical analysis.

STARCH IN FLOUR

By C. L. ALSBERG
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(Read at the convention June 2, 1927)

Altho it has been assumed generally that starch is an inert constituent of flour except in so far as it is a filler or serves to furnish yeast food, there is reason to doubt the validity of this assumption. The purpose of my paper is to present to you some of these doubts. They are based primarily upon abundant evidence that different starches behave differently, a fact that might be due to differences of a chemical nature, to differences in colloidal state, or to differences in the size and shape of the granules of the different sorts of starches.

We know, as yet, too little concerning the structure of starch molecules to be able to say whether or not differences in molecular structure cause starches to behave in different ways. There is, however, an increasing accumulation of evidence that the starch granule contains a number of different substances and probably at least two polysaccharides. Besides these, hemicellulose has been reported by Ling and Nanji (1923) as present in some starches and absent in others. Furthermore, the starch granule contains phosphoric acid in organic combination, the quantity being different from species to species. Maize starch and perhaps other starches also contain fatty acid in combination, according to Taylor and Nelson (1920). Finally, the ash of different starches is different qualitatively as well as quantitatively. In short, there can be no doubt that different starch species are mixtures of substances in different proportions. Indeed, it may well be that this is true even for the starch of different varieties of the same species.

Furthermore, Fouard (1909) brought forward some evidence that the colloidal state of starch may not be the same in different species, and this may have some bearing upon the swelling of starch granules when heated in water. Whether or not this is the case, differences in swelling must result from differences in size and shape of the granules, for I (1926) found that many kinds of starch, including that of wheat, do not, when boiled, disintegrate to form a truly colloidal solution. They merely swell to form a suspension consisting of swollen granules floating more or less freely in a watery phase. Two starches might be the same in both molecular structure and colloidal state, yet if the granules are different in size and swell to different volumes when gelatinized, the resulting pastes must be different physically, for these are the factors that determine their consistency, or, as it is wrongly called,

their viscosity. Rask and I (1924) found differences in the character of the paste formed from the starch of different kinds of wheat. These differences are probably to be explained by the observation of Buchanan and Naudain (1923) that the size of the granule varies for different kinds of wheat, the strongest wheats having on the whole the smallest granules.

In dough, starch is ordinarily considered to play no rôle except as a source of fermentable carbohydrate produced by diastatic action. Yet the water-absorbing capacity of a flour must depend in some measure on the water-absorbing capacity of the starch. Rodewald (1895) has shown that gluten and flour compete for the available water and the competition of the starch is powerful, as it imbibes and holds water with great energy. Boutroux (1897) has calculated the distribution of water in dough as follows: 100 grams flour of 10% water and 10% gluten content doughed with 50 cc. water yield about 34 grams of wet gluten with a moisture content of 60-70%. Of the 50 cc. water used in doughing, the gluten will therefore take 24 cc. Thirty-six cc. remain available for the starch. The 70 grams of starch in the flour, if they imbibe 36% of water, Rodewald (1896) calculated will take up 25 cc. According to these calculations the gluten holds 24 cc. of water, the starch 25 cc., and 11 cc. are free, available as a solvent for salts and the like. In other words, the gluten and the starch hold very nearly the same absolute amounts of water. For American bread flours containing more gluten and requiring more water in doughing, the figures would of course be somewhat different. In any event, it is obvious that starch plays no mean rôle in determining the absorption of a flour.

If this be so, then the absorption of a flour must depend in some measure upon the imbibing power of its starch. We know that different species of starch take up moisture to different degrees, but we do not yet know experimentally that different varieties of the same species do so. We are, however, inclined to believe this to be so, as Buchanan and Naudain (1923) found that the granule sizes, and Rask and Alsberg (1924) found that the starch pastes of different wheats are quite variable. On this assumption, not merely the imbibing power of gluten but also the imbibing power of starch determines the variations in absorption of the several types of flours.

It is probable that not merely the imbibing power of its starch but also the location of the starch in flour is a factor in determining absorption. The microscope shows that in strong and weak flours the starch granules have different positions. In a weak flour the gluten masses have been broken up, leaving much of the starch lying rather free and directly accessible to the water used in doughing. In a strong flour most

of the granules are firmly imbedded in a gluten matrix so that water can reach them only after diffusing through a layer of gluten. Possibly the better absorption secured by the use of high-speed mixers may be due in part to better absorption by the starch.

Overgrinding a hard flour serves to free many of the starch granules from the matrix so that under the microscope such a flour resembles a soft flour. There is, however, one important difference: In a soft flour the individual free granules have not been injured, whereas in an overground hard flour there are cracked or otherwise injured granules, the number varying according to the severity of the grinding. These granules have lost, more or less, their birefringence, according to Scheffer (1919). They were shown by Alsberg and Griffing (1925) to swell and disperse more or less in water, and Huss (1922-23) found that they stain with Congo red. Hence such a flour has a greater cold-water extract than a natural one, as was first shown by Wanklyn and Cooper (1881), and recently by Alsberg and Griffing (1925), and by Shollenberger and Coleman (1926).

As some of the starch granules of such an overground flour swell, the flour itself shows a somewhat greater absorption than before overgrinding, as shown by Alsberg and Griffing (1925) and Shollenberger and Coleman (1926). Alsberg and Griffing (1925) found that the gluten, also, is altered by overgrinding and, if too severe, it is injured and its absorption is reduced. The swelling and dispersal of some of the injured granules in water change the behavior of the flour to diastase. Long ago it was shown by the observations of Brown and Heron (1879) and Maquenne (1904) that mechanically injured granules are attacked with great rapidity by diastase. This has been confirmed in my laboratory by E. P. Griffing. Therefore, if a flour is so dressed as to injure some of the starch, its fermentation rate is increased—at least in the first stages. This has been confirmed by Alsberg and Griffing (1925) and by Shollenberger and Coleman (1926). The assumption, very generally made, that the diastatic activity of a flour is always and necessarily an expression of its diastase content, is untenable. It has already been doubted by Rask and Alsberg (1924) and by Collatz (1922), who found that the starch from strong flours appeared to be more easily hydrolyzed than that from weak flours. Recently Mangels (1926) reached the conclusion that "The variation in diastastic activity of a flour appears to be due in large part to the susceptibility of the starch granule to diastase attack."

The fermentation rate of a flour must therefore depend upon at least three factors: the diastase content, the content of uninjured granules, the susceptibility to diastase attack of the uninjured granules.

We have already considered the first and second points; the third remains for discussion. It is altogether likely, in the light of the investigations of Collatz (1922) and Mangels (1926), that the raw starches of different wheats offer different degrees of resistance to diastase, tho more work upon the question is needed. Moreover, in a hard flour, as I have already pointed out, the starch is less accessible than in a soft flour. The diastase, a colloidal substance, may have to diffuse through gluten, a colloid, in order to reach most of the granules. It is known from the work of Stoward (1911) that diastase is not evenly distributed through the barley grain. It is most abundant in the scutellum of the embryo, and next in amount in the aleurone layer. There is least in the inner portion of the endosperm, the region that contains the highest amount of starch. Martin (1920) and Rumsey (1922) give reason to believe that the distribution is similar in the wheat berry. Wysman (1890) gives even some reason to believe that the diastase of the inner endosperm is different in nature from the diastase of the aleurone layer and less easily carries the hydrolysis of starch to the stage of sugar. If the diastase is not evenly distributed in the berry but indeed is present in smallest amount in the starchiest portions, it is highly probable that the greater or lesser freedom of the starch granules and their corresponding greater or lesser accessibility to the diastase may account, at least in part, for the different fermentation rates of different flours. Probably, too, this explains why Johnson and Bailey (1925) found that the addition of starch to flour increases the fermentation rate. Undoubtedly, too, the state of the starch is probably one of the causes of the increased diastatic power of severely overground flours. Another cause, according to Ford and Guthrie (1908), is that in such a flour the diastase, for mechanical reasons, passes readily into solution.

Turning now to the rôle of starch in baking, we must appreciate that diastatic action continues in the loaf until a temperature is reached which destroys the enzyme. Diastatic action cannot be very great, for according to Stone (1896) and others there is not much soluble starch in bread. As we have seen, the amount of free water available in dough is quite insufficient for anything like complete gelatinization even if we assume that some of the water held by the gluten is released as the oven's heat coagulates it—to say nothing of the loss of water by evaporation. That starch is not typically gelatinized in bread has been shown by Jago and Jago (1911) and by others. The larger part of the granules still remain intact. Nevertheless, the granules are changed, for we have found in my laboratory that, if bread crumb be mounted in anhydrous glycerin containing a little Congo red and examined with

the polarizing microscope, no individual granules showing the dark cross can be noted. Some birefringent masses are, however, still to be seen. The granules, moreover, were all stained to varying degrees with the Congo red, showing that some alteration had occurred in all cases. Normal granules do not take up the dye.

While, therefore, according to our observations, the granules in crumb are unquestionably modified, they cannot be in the condition of the granules in ordinary starch paste or jelly. If they have been converted into a gel this is an extremely concentrated one. From this fact certain inferences may be drawn bearing upon the theory of the growing stale of bread now most generally accepted. It is that as the bread ages the starch undergoes a change whereby moisture is set free with a corresponding change in the distribution of the water between the components of the crumb, a change which manifests itself in an altered texture of the crumb.[1] The evidence for this theory is primarily that starch that has been heated in water does change in the course of time. There is separation into two phases, a solid and a liquid. Like the growing stale of bread, the process is accelerated by lowering the temperature. It has been termed "retrogradation" by French investigators, and the solid phase is called retrograded or reverted starch. French investigators believe that the solid phase is formed by a process of polymerization or aggregation of the colloidally dissolved starch. Others regard the process as merely a form of syneresis, i.e., the separation or exudation of a serum from a gel, such as occurs when a dilute agar-agar or gelatin gel is allowed to age. It may, however, be questioned whether or not the process is truly syneresis, for retrogradation takes place in solutions of starch which are liquid as well as in pastes. It takes place in clear starch solutions which have been prepared by autoclaving. Moreover, retrograded starch has become insoluble. It cannot be put back into solution by merely heating. The original state of the system cannot be restored. An agar or gelatin gel which has undergone syneresis, on the contrary, may be restored to a condition much like its original state by melting it in its own exudate and allowing it to set. Moreover, we have found that in agar or gelatin gels syneresis takes place only below a certain concentration of the gel. The more concentrated the gel, the less the syneresis. It may, therefore, be doubted that "retrogradation" of starch is truly syneresis as this term is applied to ordinary gels. Syneresis usually is an easily reversible process; starch retrogradation is not.

If this be true, then one of the principal arguments in favor of the theory of the mechanism of staling under discussion, namely, that grow-

[1] A review of the subject is presented by Maurizio (1924), pp. 362-372.

ing stale is the result of a readily reversible physico-chemical change in the starch, is without force. This argument is that the fact that stale bread can be freshened by warming is due to the reversibility of the physico-chemical change in the starch at higher temperatures. If retrograded starch is permanently insoluble, why should merely warming bread restore its freshness?

Furthermore, most of the studies upon the retrogradation of starch have been made upon clear autoclaved solutions or upon relatively dilute pastes. In bread, starch exists, as we have seen, in neither of these forms. If, in crumb, it is a gel at all, it is an extremely concentrated one. In starch pastes retrogradation is progressively slower as the concentration is raised. Even in pastes of 20 per cent concentration, a concentration far less than that which occurs in bread, the retrogradation in 48 hours is not appreciable. Yet in bread staleness begins much sooner. In short, I believe it premature to accept the starch-retrogradation or starch-paste-syneresis hypothesis of staleness until we have more direct experimental evidence and are no longer so largely dependent upon reasoning by analogy. More particularly, further information is needed concerning the colloidal state of the gluten in bread. We have been able to show in my laboratory that it is not a mere inert coagulum, for heated wet gluten has by no means altogether lost its power to swell in weak acid. It still retains its colloidal properties to some degree and may have to be considered as a factor in staleness.

Are there any practical conclusions to be drawn from the considerations I have ventured to present to you today? I think it is clear that by mechanical treatment it is possible to modify the character of a flour in certain respects. This has been known to millers in a general sort of way for centuries. But today we have a better idea of the mechanism by which such modification is brought about. It should be possible to apply these ideas to practice. It is conceivable that flours with at the same time weak or deficient gluten and deficient diastatic power, might be improved by the addition of overground flour or shattered wheat starch. It is possible that such a blend could be made into a better loaf than could be made from the flour itself because it could be handled with a very short fermentation period which would not overmature the gluten. At any rate the idea seems to me worthy of some study.

If I may summarize the gist of what I have to say to you, it is that we would do well to cease ignoring the part starch plays in giving bread and flour its character. Gluten, it is true, gives to flour its peculiar traits. It is the presence of gluten that distinguishes wheat flour from the flour of other grains. As cereal chemists the study of gluten is

our major problem; but let us not forget that starch helps to give flour its character. In our study of milling and baking, let us not forget that it plays a rôle, though a modest and a minor one.

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VALUE OF THE LABORATORY REPORT TO THE FLOUR BUYER

By A. D. Wilhoit

Minneapolis, Minn.

(Read at the convention May 30, 1927)

I am to tell you about the value of a laboratory report to the flour buyer, but I am not going to take up much of your time for I would like to have some discussion from the floor on this subject and see how well satisfied you are that we are giving the buyer as satisfactory and as understandable a report as possible or if we can possibly make it more valuable and necessary.

I thoroly believe in the value of laboratory service. If I did not I would not be in it. The cereal chemist has made his growth within the time of a number of us. He originally began his existence as an aid to the flour mills and that is where he was of most value for some time. But now he is also becoming an important addition to the baking end of the industry. In the beginning the path was just as difficult with the manufacturing as it has been with the baking, but now both the baker and the buyer of flour as well as the miller have found that there is a most important place for the chemist, and you will find the chemist will occupy a more important place in the future.

With the manufacturer our problem has been to maintain as nearly uniform a flour as possible and also to assist in making that flour at as reasonable a cost as possible, consistent with quality. The chemist's value to the mill does not decrease, but he will be more valuable as it

becomes necessary to look more carefully over the wheats we get from year to year. Likewise we find the baking trade and buyers of flour are looking more and more to the chemist for assistance. We have not been giving the buyer service as long as we have the miller, but it is important to him and he is, as you know, asking more frequently for a laboratory report.

Just at present the cereal chemist does not have the same position in his field as does the iron and steel chemist or the cement chemist, but we are making rapid progress in the profession.

The main value of a laboratory report to anyone is its interpretation and sometimes that is difficult, especially to one who is not thoroly familiar with it. It is confusing to the average buyer to have each chemist use an apparently different form of laboratory report. A chemist would no doubt be able to compare various reports and interpret them, but would the man who really needs them most and does not have a chemist available to do it for him? I should like very much to see the time when laboratory report forms, especially those going to the trade, are made more uniform in the various items and systems of markings. When that is done I believe we will have taken a forward step in making them more profitable to the average interested party and more interest will be taken in laboratory reports in general.

As a suggestion, if you please, I would like to see a uniform volume reporting system and a uniform color marking system, so that different laboratories may report on the same flour with the assurance that their results will be comparable with those furnished by another. As it is, the reports we send out are of more value to those who are familiar with our system of marking, and yet both may be telling the same thing only with different figures.

As an illustration I want to give you an extract from a letter recently received: "We insist upon this mill furnishing your analysis as we have realized we cannot compare one laboratory's figures with another's." It is not a question of accuracy, as I see it, but it is the form in which the report is made. No doubt this experience is common to each of you. I mention this because part of the value of a laboratory report is lost to the buyer when there is not a fairly standard form and system of marking.

The usual laboratory report gives moisture, ash, protein, or gluten content, together with baking results. All these are necessary in determining the quality of that flour and no flour should be passed or rejected by one alone.

There are two main things that I believe a buyer wants to know about the flour he buys. He wants to know if he is getting the grade

he has bought and if the baking results will be uniform so that the flour will fit into his shop conditions. For he does not like to change conditions and throw off his shop routine. It might be easier to change flours than to change conditions.

The report which we hand to the buyer should present a possible picture of what that flour is going to do in the bake-shop, and whether he can expect the same results as usual. Bakers are more interested in flour, either weak or strong, if they know it is always to be that way. They do not want one car low-protein and the next car high-protein. They want uniformity, and it is the report from the chemist which gives them this information.

The moisture and ash reports help to give information as to the uniformity of milling, but even with ash there is the matter of interpretation, for, because a standard patent flour may be 0.45 ash, does not necessarily mean that the same grade of flour cannot have 0.48 and be just as good. The ash varies to some extent from year to year and will, without doubt, have some variation occasionally throughout the year. Next year the wheat crop both here and in the Northwest may produce a flour with higher ash content but with no lower baking quality. The ash alone is of little value in determining the baking possibility and should be so considered. Baking results have proved many times that some flours with high ash give better results than flours with low ash and of the same grade.

The amount of protein and gluten will tell the buyer whether he is getting a flour nearly uniform in strength with previous shipments. Gluten testing is not as common, possibly, as it used to be, but I still believe it has a place, and we can convey to the buyer an idea as to the quality which may be expected in his dough. The protein figures are the more accurate, without doubt, and for that reason should be used in giving the amount of nitrogenous material. Here, also, judgment must be used, because should the protein be a few tenths lower or higher than a former car that does not mean that baking results will be different, and the flour should not be rejected for this alone.

I have just taken ash and protein as illustrations that the whole value of a laboratory report cannot be gotten from just one item, but flour should be judged by all tests, the chemical as well as the baking. The chemist, whether he is in the service of miller or baker, should not knowingly permit erroneous conclusions to be drawn from a report.

The baking report usually consists of items covering both outer and inner characteristics of the loaf. We tell of the volume of loaf, general appearance, color of crumb, texture, and grain, so that the one who gets the report will know about what to expect in his shop.

In laboratory reports we endeavor to express in figures a definite idea of the flour and tell the buyer or other interested party the grade and uniformity in color and whether it has the same baking characteristics as usual. All figures should be given consideration in passing on the flour.

You are going to have a sufficient amount of discussion on the baking test tomorrow, but I want to say that the more definite the picture can be made, that much more interested in our work the baker will be.

REPORT OF THE FIRST INTERNATIONAL CONFERENCE ON FLOUR AND BREAD MANUFACTURE IN PRAGUE, CZECHOSLOVAKIA[1]

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For the first time in the history of the cereal industry an international conference on flour and bread manufacture has taken place. This conference was held in Prague, Czechoslovakia, on September 22-25, 1927. Immediately after the conference opened, Dr. Jan Jelinek was elected presiding officer. Other officers of the conference were: general secretaries, Dr. Francis Hruska and Dr. Karel Krtinský; treasurer and interpreter of the French language, Captain Bohumil Sucharda; quartermaster-chief, Jan Horel; and director of the conference office, RNC Miroslav Sebor. In addition to being one of the general secretaries of the conference, Dr. Hruska was also elected general referee and editor of the conference publication. At his suggestion a cablegram was sent by the conference to President Olsen of the A.A.C.C. in response to the greetings of that association, which were delivered by the writer. Members of the executive committee were Vladimir Pokorny (member of the A.A.C.C.), Josef Kulman, Karel Branberger, Alois Kase, and Bohumil Svoboda.

Other prominent investigators in the field of cereal chemistry and the related sciences were also present. Among them were Dr. Alexius A. J. De Sigmond, Dr. Eugen Hankoczy, Dr. Josef Adorjan, and Dr. Emil Varsanyi, of Budapest; Dr. M. Arpin and Mlle. Pécaud, of Paris; Dr. Ernst Berliner and Dr. Kurt Ritter, of Frankfurt a. M.; Dr. D. W.

[1] Published with the approval of the Director of the Montana Agricultural Experiment Station.

Kent-Jones, Dr. H. K. Parker, Dr. E. F. Thomas, and J. H. Baker, of England; Dr. Stoklasa, of Prague; Dr. Holger Jørgensen, of Copenhagen; Dr. G. van der Lee and Dr. L. Elion, of Holland; Dr. S. Camilla, Dr. I. Giordani, and Dr. S. Stucky, of Italy; Dr. K. Laine, of Finland; Dr. Toni Masling, of Cologne; Dr. Otto von Czadek, of Vienna; and Dr. Wscisl, of Warsaw.

Evidence of the success of the conference is shown by the large number of countries represented and the large number of delegates present. There were 250 registered delegates, representing 15 European countries and the United States of America. Sixty of the delegates were from countries other than Czechoslovakia. The European countries represented were Great Britain, France, Belgium, Holland, Denmark, Germany, Czechoslovakia, Italy, Austria, Jugoslovakia, Poland, Hungary, Finland, Bulgaria, and the Soviet Republic of Russia. The interest of the Czechoslovakian government is indicated by the fact that T. G. Masaryk, president of the Czechoslovakian Republic, expressed the desire to be completely informed concerning the results of the conference. Further evidence of the interest in the conference is shown by the large number of papers presented and the great variety of subjects with which they dealt. Altogether 49 papers were presented. The wide scope of their interest is shown in the program of the conference which follows.

Jan Zák, Breclav, CSR.: Milling and baking value of Czechoslovakian wheats.

V. Kocka, Prague: Silo "Suka" with the aeration of the chambers.

Karel Branberger, Prague: Effect of the art of milling and grade of wheat flour on its quality.

Karel Krtinský, Prague: Improved flour milling after previous chemical peeling of the berry.

Prof. S. Camilla, Torino, Italy: Uniform type of flour in Italy and advantages resulting from the peeling of the berry in moistened condition.

F. Haluska, Brno, CSR.: Requirements of the bakers concerning the quality of flour and bread.

J. Mertl, Prague: Why the Czechoslovakian baker is buying foreign flour.

D. W. Kent-Jones, Dover, England: Improving baking quality by physical means.

O. Touzimský, Prague: Improvement of the grain and flour in a physical way by means of a special apparatus.

Wilhelm Brabender, Duisburg, Germany: The maturing of flour by means of air nitrogen.

H. K. Parker, London: An industrial application of nitrogen trichloride.

Otto Czadek, Vienna: Methods of flour maturing.

W. Kranz, Frankfort a. M., Germany: The Humphries process.

G. Van der Lee, Deventer, Holland: The scientific side of the effect of Novadelox on flour.

J. Kulman, Pilzen, CSR.: Correlation of the baking value of rye flour to the optimal quantity of the loosening gas in the manufacture of Pumpernickel.

B. Svoboda, Prague: Technical and economical discipline in the baking shop.

F. E. Thomas, Manchester, England: Improving baking value by chemical means.

J. R. Chittick, Chicago, Ill., U. S. A.: Baking powders, their composition and application.

L. Elion, Haag, Holland: Improvement of fermentation by chemical means.

F. Jirásek, Prague: Requirements of the consumer for the quality of bread.

Prof. St. Ruzicka, Bratislava, CSR.: Criticism of all manipulations carried out with grain and flour from the standpoint of national health and national nutrition.

Prof. J. Stoklasa, Prague: Modern opinions on the nourishment of the human and animal organism.

V. Zemlicka, Prague: The modern manufacture of margarine and its significance in the baking shop.

O. Svozil, Prague: Effect of the addition of plant oil on bread and pastry.

F. L. Dunlap, Chicago, Ill., U. S. A.: Good bread.

F. Hruska, Prague: Effects of artificial flour improving on the food value of bread and on health.

G. Van der Lee, Deventer, Holland: New laboratory apparatus for the determination of the dough consistence and bread volume.

J. Koblic, Prague: Sand in flour.

B. Sucharda, Prague: A new method for the microscopy of flour.

J. Koblic, Prague: Determination of flour grade by determining its ash content.

C. G. Harrel, New York, U. S. A.: Testing and use of flour in bread production.

J. Koblic, Prague: Determination of flour grade by determining its fat content.

K. Krtinský, Prague: Determination of the grade of flour on the ground of its chemical analysis.

C. H. Bailey, St. Paul, Minn., U. S. A.: The rôle of hydrogen ions in bread production.

Arnold H. Johnson, Bozeman, Montana, U. S. A.: Factors influencing the viscosity of flour-water suspensions.

R. Urban, Prague: Importance of the popularization of knowledge on grain, flour and bread.

Mlle. Pécaud, Paris:

a) French state milling school.

b) Baking test (description of the method).

M. Arpin, Paris:
- a) Requirements of millers for the quality of grain.
- b) Method for control of the milling process and the milling products.
- c) Requirements of bakers for the quality of flour.

Kurt Ritter, Frankfort a. M., Germany: Flour improving by chemical means.

Wilhelm Glaser: The patented process of Steinmetz from the standpoint of human nutrition and national economy.

Kurt Ritter, Frankfort a. M., Germany: The significance of flour improving in relation to the food value of our bread nutrition.

Josef Adorjan, Budapest: Rapid water determinations in milling laboratories.

R. C. Sherwood, Minneapolis, Minn., U. S. A.: Diastatic activity in flour milling.

Jan Micka, Guelph, Canada: A comparison of the American and European art of milling.

The papers which created the most discussion were those which were concerned with bleaching or maturing or treating the flour in any way. Those present at the conference might be divided into three groups according to their beliefs regarding flour treatment. One group proposed the rejection of all methods for the artificial treatment of flour. Professor of Hygiene Ruzicka, Bratislava, CSR., was the leader of this group. Another group proposed the rejection of all flour-bleaching methods because, as was stated by this group, not only did bleaching have no economic advantages but such treatment had disadvantages and might mislead the public. Dr. Otto Maier, general director of the Budapest mills and delegate from two associations of Hungarian millers, was the leader of this group. The third group proposed admitting all bleaching and flour-improving methods in all countries. Formal proposals embodying the ideas of these three groups were presented for action. It was decided, however, that the conference was not the suitable body to make decisions on such questions nor did it have the authority. The matter was, therefore, left to a committee whose report will be made at a later congress (in Rome 1929).

It appears to the writer that the most important work of the conference was the laying of the foundation for future international meetings of those interested in both the practical and the scientific problems associated with the cereal industries. In order to provide for future meetings, four definite proposals were presented to the conference and were accepted by that body. These proposals were as follows:

1. The First International Conference on Flour and Bread Manufacture, in Prague, proposes that international congresses on flour and bread manufacture be held periodically.

2. The First International Conference on Flour and Bread Manufacture, in Prague, proposes that such congresses be held biennially.

3. The First International Conference on Flour and Bread Manufacture, in Prague, proposes that the First International Congress on Flour and Bread Manufacture be held in Rome in 1929.

4. The First International Conference on Flour and Bread Manufacture, in Prague, proposes the creation of an international committee for permanent organization of international congresses on flour and bread manufacture, the general secretary of this international committee to reside in Prague. The statutes of this international committee shall be worked out by the preparatory committee for the First International Conference on Flour and Bread Manufacture, in Prague, and presented to the First International Congress on Flour and Bread Manufacture in Rome, in 1929.

As already stated these propositions were formally accepted by the conference.

One of the purposes of an international organization such as this should obviously be the development of standard physical and chemical methods for making the tests to which cereals and cereal products are subjected. It was therefore formally proposed and the proposition was accepted by the conference that "within the permanent international committee for organization of periodical international congresses on flour and bread manufacture, such committee having headquarters in Prague, there shall be created a special international commission to work out uniform analytical methods for cereal chemistry. The working out of these methods shall be accomplished in the shortest time possible so that equivalent and comparable analytical results may be obtained in every country and in every laboratory." The writer then explained to the conference what was being done in this regard by the American Association of Cereal Chemists and told of the book of methods which the Association is publishing. The proposition was therefore adopted that "The methods of the A.A.C.C., as published in 1927, will be used as a basis for working out the international methods."

The general report of the conference containing the discussions as well as the papers which were presented will be published. From this publication the work of the conference may be learned in greater detail.[2]

The proceedings of the conference will be printed in both the Czechoslovak and French languages. The papers will be printed in

2 This publication may be obtained for $3.50 from Dr. Francis Hruska, State Institute for Food Research, Charles University, Prague II, 1660 Na Bojisti 3, Czechoslovakia.

the language in which they were read, i. e. Czechoslovak, French, German, or English, and summaries of each paper will be printed in all four languages.

It was recognized by those who organized the First International Conference on Flour and Bread Manufacture, in Prague, that the most important work of the conference would be the establishment of a permanent body to arrange for future international congresses on flour and bread manufacture. The success of such congresses necessarily depends on the existence in every country of organized groups interested in cereal problems. In the United States the American Association of Cereal Chemists is such a group. In all other countries it will be necessary to organize such groups. These groups may then elect their delegate to future congresses. It was hoped that the international conference in Prague might assist in the organization of national associations, hence thereby assist also in the organization of international congresses on flour and bread manufacture. It is with the purpose of organizing such national associations that the delegates who attended this First International Conference on Bread and Flour Manufacture will return to their respective countries. Since our own association in the United States is already organized and functioning, it is expected to give moral support to future international congresses on flour and bread manufacture and to cooperate, when it can, with the committee for permanent organization of international congresses on flour and bread manufacture.

INDEX—AUTHOR AND SUBJECT

Page

Abbott, R. C., M. J. Blish, and H. Platenius. The quantitative estimation of glutenin in wheat flour 129
Absorption
  Tables for calculating to a 15% moisture basis. A. W. Meyer 68
  Measuring with penetrometer. C. G. Harrel 283
Albumin of flour, preparation and analysis. W. F. Hoffman and R. A. Gortner 221
Alsberg, C. L. Starch in flour 485
Alsberg, C. L. and E. P. Griffing. The heat coagulation of gluten..... 411
Amino acids, estimation in wheat and flour. H. J. Denham and G. W. Scott Blair 58
A. O. A. C., collaboration with, R. Hertwig 474
Ash
  Determinations, collaborative studies of methods. D. A. Coleman.. 317
  In flour streams. E. P. Harding and George Dysterheft 47
  In flour, contribution to the determination of. J. Micka 461
Bailey, C. H.
  What progress are we making as cereal chemists 275
  and R. A. Barackman. The rôle of phosphates in bread making... 400
  and Emily Grewe. Relation of hydrogen-ion concentration of dough to baking properties 261
  and R. C. Sherwood. Observations of baking tests 305
  and Herbert Vogel. A study of durum wheats 136
Bailey, L. H. Comments on baking test 303
Bakery engineer, relation of work to that of flour mill chemist. E. B. Price 470
Baking properties and H-ion concentration. Emily Grewe and C. H. Bailey 261
Baking test
  Some factors influencing. R. S. Herman and V. M. Hart 157
  Interpretation of. L. W. Haas 389
  Report of committee on standardization, M. J. Blish, Chairman.... 299
  Factors affecting interpretation. M. J. Blish and R. M. Sandstedt.. 291
  Basis for standardization. M. J. Blish 149
Baking value, determination of. Marcel Chopin 1
Barackman, R. A. and C. H. Bailey. The rôle of phosphates in bread making 400
Biscuits, measurement of volume. R. E. Lyons 481
Blair, G. W. Scott, and H. J. Denham. Estimation of amino acids and proteolytic activity in wheat and flour 58
  and G. Watts and H. J. Denham. Effect of concentration on viscosity of flour suspensions 63
  and G. Watts and H. J. Denham. Notes on the use of Ostwald viscometer for flour suspensions. 206
Blish, M. J.
  A rational basis for the standardization of the experimental baking test. 149
  and R. C. Abbott, and H. Platenius. The quantitative estimation of glutenin in wheat flour 129
  and R. M. Sandstedt. Factors affecting interpretation of experimental baking tests 291
Book review. Bread Baking, by M. H. Joffe, reviewed by J. A. Dunn .. 435
Bread quality of, as influenced by application of nitrogen at different stages of growth. W. F. Gericke 73
Bread making, rôle of phosphates in. R. A. Barackman and C. H. Bailey.. 400
Buffer value, in testing flour. C. G. Harrel 423
Buyer of flour, value of laboratory report to. A. D. Wilhoit 492

Page
Calcium acid phosphate, neutralising value of. C. W. Herd 347
Calcium in flour streams. E. P. Harding and George Dysterheft 47
Cereal chemists, progress made by. C. H. Bailey 275
Chlorine, effect on gluten quality. T. R. James and J. X. Huber 454
Chopin, Marcel. Determination of baking value of wheat by measure of specific energy of deformation of dough 1
Chromate solutions for gasoline color value determinations. H. Jørgensen 468
Clark, R. J. Address of the president 327
Coagulation of gluten by heat. C. L. Alsberg and E. P. Griffing 411
Coleman, D. A. Report of the committee on methods of analysis for the American Association of Cereal Chemists 311
Color analysis of durum wheat flour. Herbert Vogel and C. H. Bailey.. 143
Deformation of dough, specific energy of, and baking value. Marcel Chopin. 1
Denham, H. J., G. W. Scott Blair, and G. Watts
Estimation of amino acids and proteolytic activity in wheat and flour 58
Notes on the use of Ostwald viscometers for flour suspensions.... 206
Effect of concentration on viscosity of flour suspensions 63
Density of wheat as influenced by freezing, stage of development, and moisture content. P. F. Sharp 14
Development of wheat and density. P. F. Sharp 14
Diastatic activity
and H-ion concentration. Emily Grewe and C. H. Bailey 263
and starch granules. Emily Grewe and C. H. Bailey.....243
Dough, specific energy of deformation and baking value. Marcel Chopin 1
Drying, rate of, in wheat flour, starch, and gluten. E. A. Fisher 184
Dunn, J. A. Book review, Bread Baking by M. A. Joffe 435
Durum wheats, a study of. Herbert Vogel and C. H. Bailey 136
Durham, R. K. Secretary-treasurer's report 334
Minutes of 13th convention 333
Extensibility of doughs made with various types of wheat flour. Emily Grewe and C. H. Bailey 239
Extensimeter, and baking value. Marcel Chopin 1
Fat content of flour, estimation of. C. W. Herd 370
Ferrari, C. G. Report of the managing editor 336
First International Conference on Flour and Bread Manufacture. A. H. Johnson 495
Fisher, E. A. A study of the rate of drying of wheat flour, starch, and gluten 184
Flour, H-ion determination and buffer value in testing. C. G. Harrel .. 423
Flour, rate of drying. E. A. Fisher 184
Flour streams, iron, calcium, magnesium, phosphorus, ash, and protein content. E. P. Harding and George Dysterheft 47
Freezing, influence on density of wheat. P. F. Sharp 14
Gasoline color value, chromate solutions for. H. Jørgensen 468
Gericke, W. F. On the quality of bread from wheats supplied with nitrogen at different stages of growth 73
Globulin in flour, preparation and analysis. W. F. Hoffman and R. A. Gortner 221
Gluten
A study of the physical properties. T. R. James and L. X. Huber.. 449
heat coagulation of. C. L. Alsberg and E. P. Griffing 411
rate of drying. E. A. Fisher 184
Glutenin
Concentration in wheat flours. Emily Grewe and C. H. Bailey.... 230
determinations, collaborative studies of methods. D. A. Coleman.. 320
estimation in flour. M. J. Blish, R. C. Abbott, and H. Platenius . 129
Extraction from flour. P. F. Sharp and B. L. Herrington 254

Page

Gortner, R. A. and W. F. Hoffman. The preparation and analysis of the various proteins of wheat flour with special reference to the globulin, albumin, and proteose fractions 221
Grewe, Emily and C. H. Bailey. Relation of hydrogen-ion concentration of dough to baking properties 261
Griffing, E. P. and C. L. Alsberg. The heat coagulation of gluten..... 411
Grinding, effect on gluten quality. T. R. James and L. X. Huber..... 452
Haas, L. W. Interpretation of baking tests 389
Harding, E. P. and George Dysterheft. A determination of iron, calcium, magnesium, phosphorus, ash, and protein in hard spring wheat and in the flour streams representing the largest volume of flour produced in its milling 47
Harrel, C. G.
A gravimetric penetrometer for measuring stiffness or toughness of doughs 283
An automatic proof box 278
Value of hydrogen-ion concentration and buffer value determination in testing and use of flours 423
Hart, V. M. and Ralph S. Herman. Some factors influencing the experimental baking test 157
Herd, C. W.
Estimation of the neutralising value of acid calcium phosphate.... 347
Estimation of fat content of flour and milling stocks 370
Herman, Ralph S.
Varying characteristics of three types of wheat grown under the influence of identical environment. II The 1926 crop 436
Value of experimental milling test 270
and V. M. Hart. Some factors influencing the experimental baking test. 157
Herrington, B. L. and Paul F. Sharp. Wheat and flour studies XI. Note on the extraction of proteins from wheat flour. 249
Hertwig, Raymond. Collaboration with the Association of Official Agricultural Chemists 474
Hoffman, W. F. and R. A. Gortner. The preparation and analysis of the various proteins of wheat flour with special reference to the globulin, albumin, and proteose fractions 221
Huber, L. X. and T. R. James. A study of the physical properties of washed gluten 449
Hydrogen-ion concentration
Value in testing flours. C. G. Harrel 423
Collaborative studies of methods. D. A. Coleman 321
and baking properties. Emily Grewe and C. H. Bailey 261
Hydrochloric acid, effect on gluten quality. T. R. James and L. X. Huber 457
Iron in flour streams. E. P. Harding and George Dysterheft 47
James, T. R. and L. X. Huber. A study of the physical properties of washed gluten 449
Johnson, A. H.
Wheat and flour studies X Factors influencing the viscosity of flour-water suspensions I. Effects of temperature, degree of hydration, and method of manipulation 87
Report on the First International Conference on Flour and Bread Manufacture in Prague, Czechoslovakia 495
Jørgensen, Holger.
Use of chromate-solutions as comparison-standards for the determination of "gasoline color values." 468
Kent-Jones, D. W. "A study of the effect of heat upon wheat and flour especially in relation to strength." Review by editor 72
Lyons, R. E. A method for the precise measurement of the volume of test biscuits 481

Page
Magnesium in flour streams. E. P. Harding and George Dysterheft.. 47
Mangels, C. E. Pre-harvest factors which affect wheat quality..... 376
Merriam, C. F. Translation of paper by Marcel Chopin 1
Methods
Measurement of the volume of test biscuits. R. E. Lyons..... 481
Contribution to the determination of ash in flour. Jan Micka..... 461
Estimation of neutralising value of acid calcium phosphate. C. W. Herd 347
Estimation of fat content of flour and milling stocks. C. W. Herd.. 370
Report of A. A. C. C. committee. D. A. Coleman, chairman 311
Baking test standardization. M. J. Blish 299
A gravimetric penetrometer for measuring stiffness or toughness of doughs. C. G. Harrel 283
Extraction of proteins from flour. P. F. Sharp and B. L. Herrington 249
Estimation of glutenin in flour. M. J. Blish, R. C. Abbott, and H. Platenius 129
Estimation of amino acids and proteolytic activity in wheat flour. H. J. Denham and G. W. Scott Blair 58
Meyer, A. W. Conversion tables for calculating the absorption of flour to a 15.0% moisture basis 68
Micka, Jan. Contribution to the determination of flour ash 461
Milling test, value of. R. S. Herman 270
Minutes of 13th convention A. A. C. C. R. K. Durham 333
Moisture
Collaborative studies of methods. D. A. Coleman 311
Content and density of wheat. P. F. Sharp 14
Morison, C. B. Comments on experimental baking tests 309
Nitrogen, effect on quality of wheat when applied at different stages of growth. W. F. Gericke. 73
Nitrogen trichloride, effect on gluten quality. T. R. James and L. X. Huber 453
Ostwald viscometers for flour suspensions. H. J. Denham, G. W. Scott Blair and G. Watts 206
Penetrometer for measuring stiffness or toughness of doughs. C. G. Harrel 283
Phosphate, neutralising value of acid calcium. C. W. Herd 347
Phosphates, rôle of, in bread making. R. A. Barackman and C. H. Bailey 400
Phosphorus in flour streams. E. P. Harding and George Dysterheft.. 47
Platenius, H., M. J. Blish, and R. C. Abbott. The quantitative estimation of glutenin in wheat flour 129
Preharvest factors which affect wheat quality. C. E. Mangels 376
President's address. R. J. Clark 327
Price, E. B. The work of the bakery engineer in relation to that of the flour mill chemist 470
Progress of cereal chemistry. C. H. Bailey 275
Proof box, an automatic. C. G. Harrel 278
Proteins
Concentration in various types of wheat flour. Emily Grewe and C. H. Bailey 230
Determinations, collaborative studies of methods. D. A. Coleman... 313
Extraction from flour. P. F. Sharp and B. L. Herrington 249
In flour streams. E. P. Harding and George Dysterheft 47
Of durum wheat. Herbert Vogel and C. H. Bailey 136
Of wheat flour, preparation and analysis. W. F. Hoffman and R. A. Gortner 221
Proteolytic activity, estimation in wheat and flour. H. J. Denham, and G. W. Scott Blair 58
Proteose of flour, preparation. W. F. Hoffman and R. A. Gortner 221
Registration of Omaha Convention of A. A. C. C., 1927 343

Page
Report on flour, value to the flour buyer. A. D. Wilhoit 492
Sampling flour, methods of. H. Runkle 323
Sandstedt, R. M. and M. J. Blish. Factors affecting interpretation of experimental baking tests 291
Secretary-treasurer's report. R. K. Durham 334
Sharp, P. F.
Wheat and flour studies, IX Density of wheat as influenced by freezing, stage of development, and moisture content 14
and B. L. Herrington. Wheat and flour studies XI. Note on the extraction of proteins from wheat flour 249
Sherwood, R. C.
and C. H. Bailey. Observations of baking tests 305
Surveying the new wheat crop 395
Specific energy of deformation of dough, and baking value. Marcel Chopin 1
Spectrophotometric study of durum wheat flour. Herbert Vogel and C. H. Bailey 143
Starch
In flour. C. L. Alsberg 485
Granules and diastatic activity. Emily Grewe and C. H. Bailey .. 243
Rate of drying. E. A. Fisher 184
Surveying the new wheat crop. R. C. Sherwood 395
Tables for calculating the absorption of flour to a 15% moisture basis. A. W. Meyer 68
Temperature, influence on viscosity of flour suspensions. A. H. Johnson. 87
Viscometers, Ostwald for flour suspensions. H. J. Denham, G. W. S. Blair, and G. Watts 206
Viscosity
Of flour suspensions, effect of concentration. G. W. Scott Blair, G. Watts, and H. J. Denham 63
Of flour-water suspensions as influenced by temperature, degree of hydration and method of manipulation. A. H. Johnson.... 87
Of suspensions of various types of wheat flour. Emily Grewe and C. H. Bailey 240
Of durum flour suspensions. Herbert Vogel and C. H. Bailey ... 136
Vogel, Herbert, and C. H. Bailey. A study of durum wheats..... 136
Volume of test biscuits, method of measuring. R. E. Lyons 482
Watts, G., H. J. Denham and G. W. Scott Blair
Effect of concentration on viscosity of flour suspensions 63
Notes on the use of Ostwald viscometers for flour suspensions 206
Wheat
Characteristics of three types, 1926 crop. R. S. Herman 436
Crop, surveying the new. R. C. Sherwood 395
Density of, as influenced by freezing, stage of development and moisture content. P. F. Sharp 14
Quality and pre-harvest factors. C. E. Mangels 376
Whiting, L. D. Comments on experimental baking tests 310
Wilhoit, A. D. Value of the laboratory report to the flour buyer 492

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